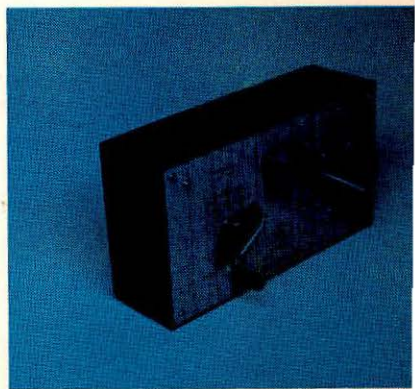
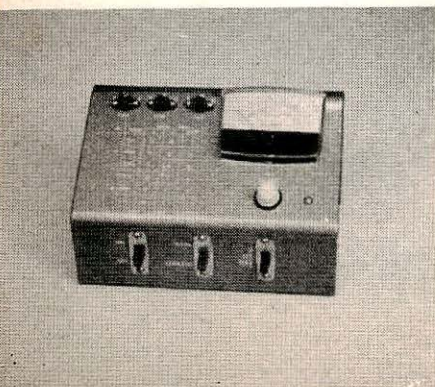
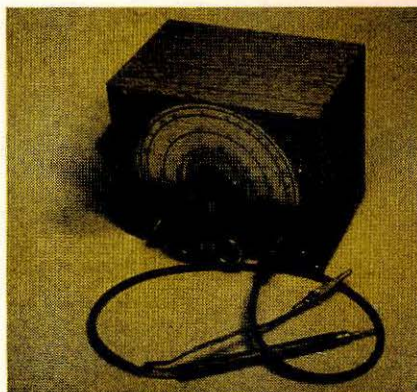
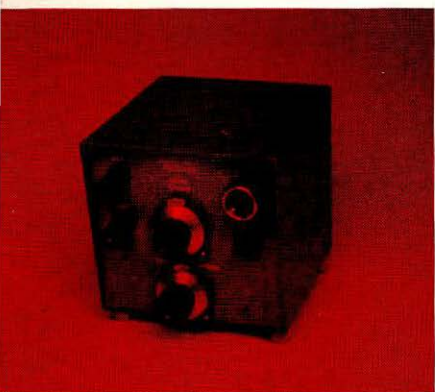


Practical Test Instruments You Can Build



**Edited by
Wayne Green**



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Preface

The articles included in this book represent the best that technology has to offer. Selected from the pages of 73 Magazine on the basis of their general usefulness to all members of the electronic professions, these test-equipment projects have several unique attributes in common: They are, for the most part, capable of being built and put to use in a single evening; they make optimum use of inexpensive components, and they all offer a utility that makes them well worth every minute of the time required to assimilate the components and build the circuits.

Not every reader will find every circuit project attractive, of course. How many, for example, will wish to build their own frequency counter or waveform synthesizer? But there are enough projects of different varieties to appease the construction appetites of any technician or experimenter. And it only takes one simple project, completed successfully, to make the book a sound investment.

To make this book easy to use and handy as a source of circuits for reference, the project areas have been divided into these discrete sections: semiconductor testing devices; measuring volts, ohms, and rf watts; dipmeters and wavemeters; and, as a kind of "catch-all," useful test and measurement circuits.

The first section (semiconductor testing devices) includes circuits that range from an ultrasimple go/no-go diode tester to a full-fledged transistor parameter testing device. The circuits in this section are applicable to diodes, transistors of every description, and integrated circuits.

Voltmeters, ohmmeters, rf wattmeters, and devices that extend the range of existing test equipment are the subjects of the second section. The wide variety of projects will allow you to choose the right circuit for your application. If you're in-

terested in measuring ~~approximate~~ power, for example, you can whip out the junkbox and build Bill Hoisington's relative-power meter—or you can go “first-cabin” with Frank Jones' high-performance hot-carrier-diode circuit.

And so it goes. Wherever your technical interest lies, we believe you'll find in these pages at least a few ideal test-equipment projects that appear to have been tailor-made to your individual requirements. This was our aim.

The Publishers

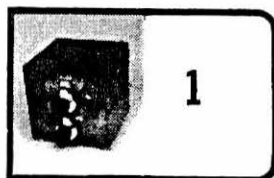
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VOM Transistor-Diode Checker

by Charles Witkowski



The ohmmeter method of checking transistors is not new, and no claim for originality in this category is made with the instrument to be described. What is to be presented is an inexpensive switching device used in conjunction with an ordinary voltohmmilliammeter to quickly measure the more common transistor parameters. We leave the more sophisticated and expensive types of transistor testers (some costing close to \$100) to the design engineers and manufacturers.

The schematic shown in Fig. 1 is straightforward and self-explanatory, the entire unit being built into an LMB box chassis $5\frac{1}{4} \times 3 \times 2\frac{1}{8}$ in.

Referring to the photo of Fig. 2 (starting at the bottom), the two insulated tip jacks marked P and N are for connection to the ohmmeter. Next in the lower center is a DPDT slide switch (S1) marked F and R for forward and reverse readings. Next, on the left is a black pushbutton E/B shorting switch. On the right is the C/B gain pushbutton. In the center on the left is an SPDT slide switch (marked S2) to connect the P line to either the emitter or collector (marked E and C).

In the center is the I_{EB}/I_{CB} leakage test pushbutton. This button, unpressed, allows a protective 27K resistor to be in series with the 3V battery and a 100 uA meter. In the event of an EB or CB short, the meter would show full-scale reading or zero ohms. If so, do not press this button, as you would end up with a blown microammeter. If the reading is in the neighborhood of 50K or more, then it is safe to press the leakage button, shorting out the 27K resistor and reading the true leakage current in microamperes.

To the right of the leakage pushbutton, in center, is an SPDT slide switch (marked S3) to connect the N line to either the base or the collector. Above the leakage button is the

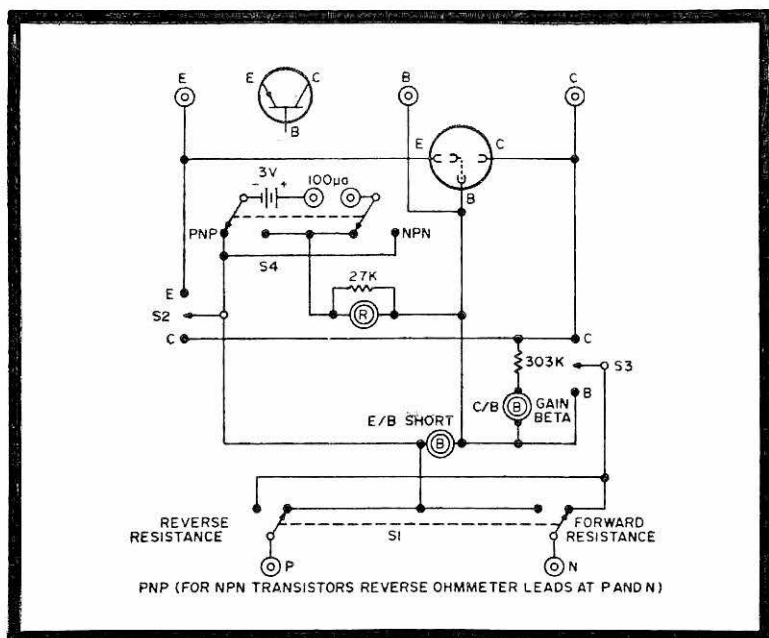


Fig. 1. Complete circuit diagram.

transistor socket, and to either side are the two tip jacks for the 100 uA meter.

On the top row are three insulated tip jacks (marked E, B, and C). Make three 6 in. leads with a phone tip on one end and a small alligator clip on the other and color-code them to match the color code of the three E, B, and C tip jacks. These will be useful in testing power diodes and power transistors. S4 (mounted on the side of the box) is a DPDT polarity-reversing slide switch used in conjunction with the internal 3V battery and the 100 uA meter for testing PNP and NPN bipolar transistors.

Placement of parts is not critical, but the symmetrical layout shown in Fig. 2 is desirable for convenient orientation of tests, as will be shown in the detailed step-by-step procedure.

The first thing to determine is the true polarity of the ohmmeter leads. Most ohmmeters, with the exception of the Simpson 260, have their polarities reversed on ohms. That is, the black or common lead is tied to the positive of the battery and the red lead is tied to the negative side of the battery. A quick check of your ohmmeter can be made as follows. Take any marked diode and measure its resistance. In one position

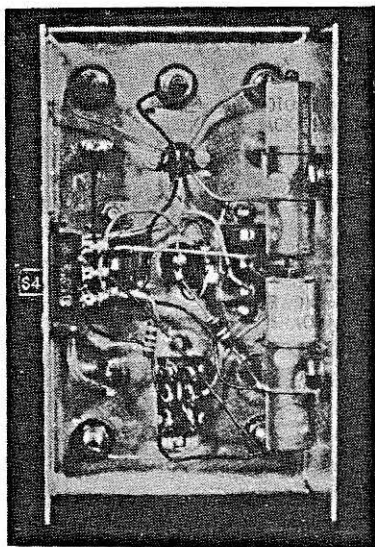


Fig. 3.

**Forward Resistance of Both Junctions.
EB—CB**

- A. Ohmmeter (Rx100 scale) leads in P and N
- B. S1 to F
- C. S3 to B
- D. S2 to E and to C

High resistance reading=open junction

Below 500 Ω reading=normal transistor

**Reverse Resistance of Both Junctions.
EB—CB**

- A. Change ohmmeter to Rx10K position
- B. S1 to R
- C. S3 to B
- D. S2 to E and to C
 - 1. Low resistance reading denotes a shorted or leaky junction.
 - 2. Low- or medium-power germanium transistors should show a resistance reading of at least 500K
 - 3. Silicon transistors should show high resistance readings
 - 4. Power transistors should show readings of 50K or greater

Current Gain

- A. Rx100 (ohmmeter scale)
- B. S1 to F
- C. S2 to E
- D. S3 to G
- E. Press CB GAIN button
 - 1. Meter should increase in current (decrease in resistance reading).

Dynamic Test (Go/No-Go)

- A. S1 to R
 - S2 to E (high resistance reading)
 - S3 to C
- B. Press EB SHORT button (reading should be less than 500 Ω)
- C. If only slight resistance change noted on pressing EB SHORT button, transistor is defective.

Leakage current

- A. Remove ohmmeter from P and N
- B. S4 to PNP or NPN
- C. +100 μ A meter lead to red 100 μ A pin jack.
- D. -100 μ A meter lead to black 100 μ A pin jack.
- E. S2 to E (press LEAKAGE button)
- F. S2 to C (press LEAKAGE button)
 - 1. Low and medium power transistors (10 to 15 μ A)
 - 2. Power transistors (100 μ A or more)
 - 3. Silicon junctions (fraction of a microampere)

Beta Measurements

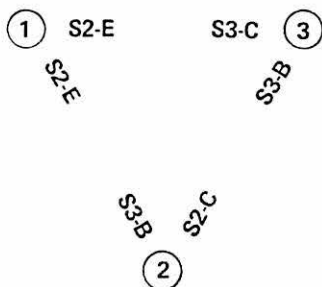
- A. Remove ohmmeter leads from P and N
 - B. S2 to C
 - C. S3 to C
 - D. + of 3V battery to emitter
 - E. - of 2 mA meter to - of 3V battery
 - F. + of 2 mA meter to collector
 - G. Press CB GAIN button (dc beta)
- $$\text{Beta} = \frac{I_c}{I_b} = \frac{1000}{10} = 100 \text{ (if meter reads 1 mA or 1000 } \mu\text{A)}$$

H. For ac beta:

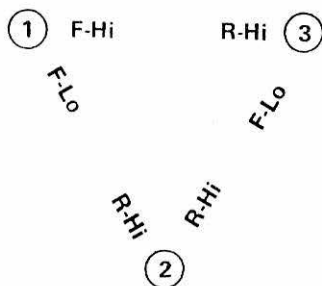
1. Take collector current reading with base open
2. Press CB GAIN button and note change in collector current (I_C).
3. Change in $I_C / 10 \mu A = ac \text{ beta}$

Base Identification

- A. Consider E as (1) unidentified lead
Consider B as (2) unidentified lead
and C as (3) unidentified lead
- b. Switch setup:



C. S1 to F and R



Base is lead not involved in the two high resistance readings in the 1-3 position above.

Unmarked Transistor Identification

A. Type PNP or NPN?

1. Low resistance reading when base is negative and positive is connected to either collector or emitter transistor is PNP.

2. Low resistance reading when base is positive and negative is connected to either collector or emitter: transistor is NPN.

B. Collector and Emitter Lead Identification

1. Take forward and reverse readings between collector and emitter.
2. The lower resistance reading signifies the negative terminal of the ohmmeter is connected to collector lead.

Diodes

A. Ohmmeter (R x 100 scale) to P and N

B. S1 to F

C. S2 to E

D. S3 to C

E. Connect anode to pin jack E

F. Connect cathode to pin jack C

G. Forward reading $500\ \Omega$ or less ($10\ \Omega$ or less on R x 1 scale)

H. S1 to R

I. Reverse reading = 50K or higher

Unmarked Diode—Cathode Identification

A. Ohmmeter (R x 100 scale) to P and N

B. S1 to F

C. S2 to E (E will be +, C will be —)

D. S3 to C

E. Connect diode to pin jacks E and C

F. Take resistance reading

G. Reverse diode at pin jacks E and C

H. Take resistance reading

I. With the low resistance, the negative lead of ohmmeter (pin jack C) will be connected to cathode.

Power Transistor Leakage and Gain

A. Ohmmeter (R x 1 scale) leads in P and N

B. S1 to F

C. S2 to E

D. S3 to C

E. Connect power transistor to corresponding pin jacks E-B-C

F. Leakage

1. The lower the ohmmeter reading, the higher the leakage.

2. Zero indication: transistor shorted.

G. Gain

1. Shunt B-C pin jack terminals with a 1.5K resistor

2. Reading of over 60 ohms: low gain

3. Reading of between 25 and 39 ohms: medium gain

4. Reading of between 6 and 12 ohms: high gain

As an exercise to check out the tester, a "surprise" pack of 25 unmarked transistors was purchased from a local radio store for \$1. Some 20 minutes later, it showed 10 PNP and 6 NPN transistors were perfectly okay; nine transistors were defective.

At a little over 6 cents each, one can be a little liberal, and in fact a little careless in his use of some of those moderately unsafe experiments and applications.

Testing Diodes With Diodes

by John McFeters

It has been my fortunate experience to have acquired a number of silicon diodes as well as signal diodes and transistors. The problem, of course, was to evaluate these units so as to make proper use of them without exceeding their peak inverse values, in some nondestructive testing arrangement.

The first problem was to obtain a burnout-proof microammeter. Surveying the equipment on the bench, I spotted a VTVM. A little further thought led me to realize this was exactly the instrument I searched for. Its input resistance is 11 megohms and in operation it is actually measuring the current through this resistance. All this means is that for each 11V read on the meter there is 1 μ A of current flowing through the meter. 10 μ A equals 110V, etc. Therefore, using a VTVM for a dropping resistor in conjunction with a variable voltage dc power supply on the order of 1000V, it is possible to "avalanche" both diodes and transistors without damaging them.

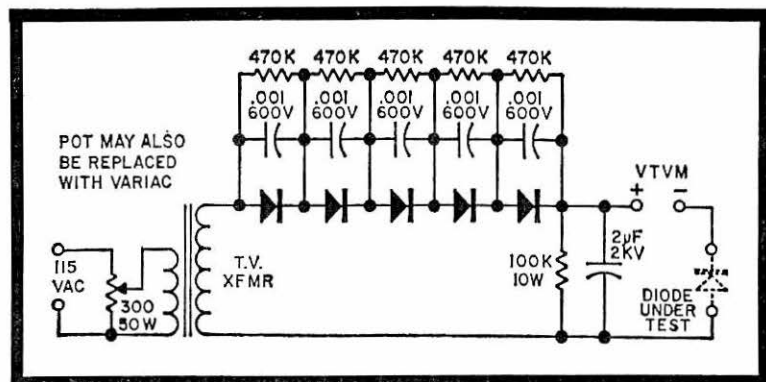
In evaluating silicon diodes for high-voltage power supplies, etc., the diodes should have less than 1 μ A of leakage. The maximum peak inverse voltage that can be safely used on a particular diode would be that voltage which produces 1 μ A of leakage or less. This would be the diode's "PIV" rating.

It has been said that once a manufacturer sets up his equipment to make "good" diodes, it's fairly difficult to make poor ones. That is to say that a great many 200 PIV diodes have actual PIV ratings of 600V and some even better.

In using these diodes for high-voltage power supplies, there are several rules which should be rigorously adhered to:

1. There should be a 0.001 μ F disc capacitor across each diode.

2. There should be a resistor of about 500K across each diode in the string. (These resistors equalize the reverse



voltage drop across each diode, compensating for individual leakage resistances. The capacitors tend to round off most high voltage transients from the power line.)

3. Allow at least 20 percent safety factor in initial design; e.g., a 2400V dc supply with 2400V ac each side of center has a peak inverse voltage of 6720V (2.8×2400). With this safety factor, the diodes should be capable of withstanding 8024V.

Low-PIV-Diode Tester

by Jim Ashe

Semiconductor diodes are almost as useful in circuit construction as resistors and capacitors. Used properly, diodes are good for all sorts of tricks beyond detecting rf and rectifying ac.

Diodes are very, very cheap when bought on the surplus market. But a certain percentage of these **cheapies** will be bad. If you've a tester handy, culling the good ones will be a breeze. And the right **kind** of tester will even give you some bonus information, too.

This simple circuit tells which end of the diode is which, what its reverse breakdown characteristics are, and it gives you a rough indication of quality. You'll have to try something else if you're interested in determining rf performance or pulse rise time and turnoff characteristics, but you can tell if it's worth further attention. The tester also checks zeners and transistors by observing the properties of their inherent diodes. And maybe there are one or two other uses for it.

The schematic is given in Fig. 1. This shows a high-voltage transformer in series with a resistor and a diode, and an output terminal added across the diode. Note that the diode points up. A second winding which provides the scope sweep voltage is not needed for a basic explanation. So let's work out what happens when the circuit is turned on. The key lies in the diode properties of reverse breakdown, forward conduction, and internal resistance.

The dotted box in Fig. 1 represents the shell of the real diode. Electronically we can never open up this shell and find something inside that visibly accounts for what the diode does. But we can suppose there's a perfect diode inside the shell, and a resistor that somewhat spoils the diode's properties. Then we can describe the real diode's behavior in terms of this model. Let's say the perfect diode goes into reverse break-

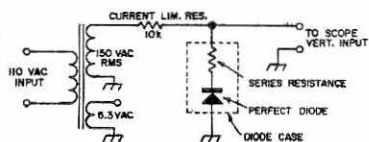


Fig. 1. Basic circuit of tester.

down at 20V, forward conduction at 0.7V (appropriate for silicon; choose 0.2V for germanium) and the resistor has the rather high value of 100 ohms.

Figure 2 illustrates the resulting situation with two superimposed curves. The upper curve represents the 150V rms sine wave, always seen at the transformer terminals. The lower curve shows what we see at the diode terminals—generally a much lower voltage. Let's follow this through a complete cycle.

Starting at zero volts and going in the positive direction, we follow the sine wave along its natural course until it reaches 20V. At this level the diode goes into conduction, and the circuit sees the 100-ohm resistor as a heavy load with its bottom end held at 20V. This state continues until the transformer's sine wave returns to the 20V level on its downward swing. Then the diode goes off, we return to the sine curve, and follow its natural course back to zero.

The 150V rms wave goes to 212V peak at the center of the half-cycle. We see roughly 200V across 10K, or about 20 mA at this instant. Passing through the diode's 100 ohms, this current adds 2V to the perfect diode's 20V. We will have to push the top of the diode voltage curve up a little bit, and we should round

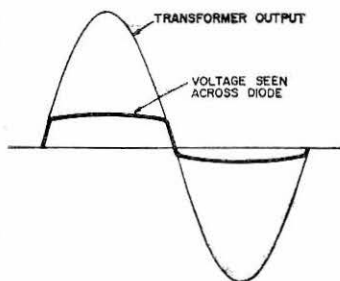


Fig. 2. Where the diode characteristic curve comes from.

off the corners since that's what we expect to find in a real circuit. This is how we get Fig. 2, which very closely resembles the real curves you will observe using a triggered or sawtooth sweep.

The negative half-cycle closely resembles the positive curve, but the break points are very much closer to zero. The (silicon) diode takes over at 0.7V rather than 20V, and the curve bulges in the opposite direction because the current flow is reversed.

A transformer with a 6V heater winding can be put to use as a horizontal sweep source. This gives a linear presentation. That is, starting at the center of the trace, which should rise toward the right, percentage of distance to the end equals percentage of peak applied voltage. This eliminates using a simple trig equation if you want to know the diode current at any part of the curve. And it gives a presentation closely resembling the manual and textbook illustrations. By changing some output connections you can get an exact correspondence.

Depending upon conditions of operation, 200V or more can appear at the tester's output terminals. If you're looking at fine detail in the diode characteristics, this could be applied directly to your scope's input tube. The 33K resistor in series with the vertical output terminal limits current flow under these and short-circuit conditions to 5 mA or so at the price of a slight loss in signal amplitude. A much larger current is available at the diode test terminals, so watch your fingers! Turn the tester off when changing diodes.

Construction

Figure 3 shows a complete schematic of the tester. Those protective resistors and the two-pole power-switch might seem a little elaborate, but they add up to a pretty fair insurance policy.

A 5x7x2 in. chassis serves as case and panel, and a bottom plate makes a worthwhile improvement. All wiring is point-to-point, and three 11-lug solder strips provide additional useful tie points. Figure 4 shows a bottom view of the tester.

You can see the transformer in the lower left corner of the chassis. The ac cheater-cord connector goes beside the transformer, with a half-inch of clearance around its solder lugs. The fuse-holder is in the same wall, some two inches forward.

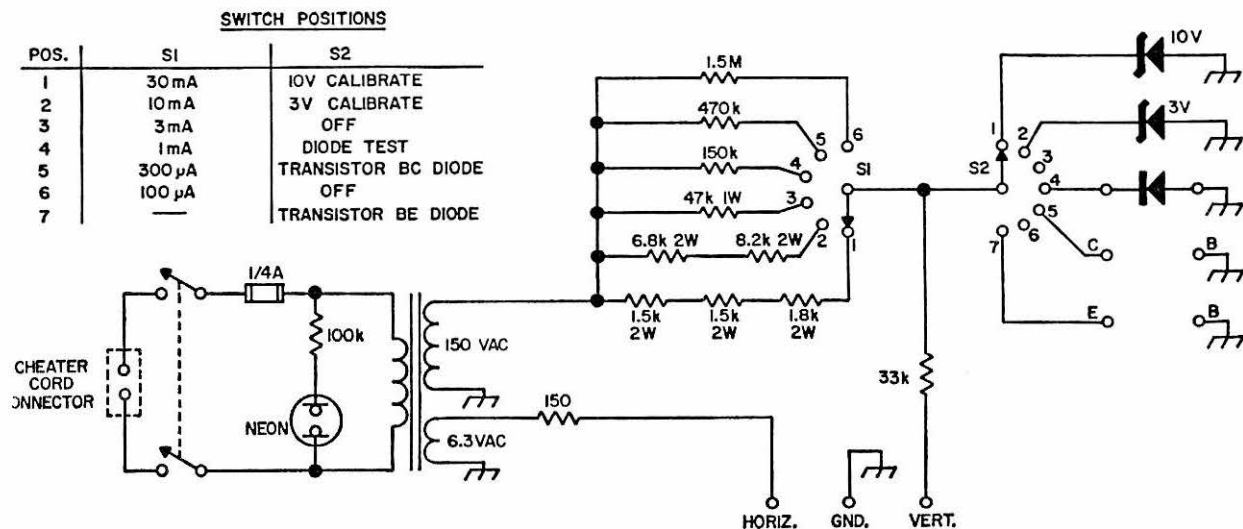


Fig. 3. Complete schematic of the diode tester.

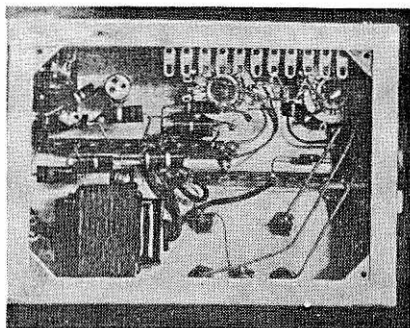


Fig. 4. Bottom view of the tester. The calibration zeners are on the lug strip at the upper right corner of the chassis.

On the top surface, three rotary switches and a neon pilot lamp are mounted on the same line slightly more than one inch from the front wall. (See Fig. 5.) With the transistor and diode terminals toward the rear, there is a clear area across the inside of the chassis which takes two of the three 11-lug strips.

Banana jacks make for effective test and output connections. They seem to be more convenient than anything else. Figure 6 shows a collection of connecting adapters made up for the tester. The ones on the left are made up of Grayhill breadboarding terminals soldered onto banana plugs, and they are particularly handy when testing diodes. The others are made up of banana plugs and some light and heavy wire,



Fig. 5. Tester is finished with slow-drying enamel. Letters can be pressed on with dry-transfer dial markers.

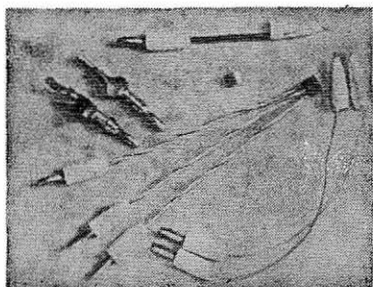


Fig. 6. Assorted leads for tester.

with Mueller clips. Use "micro" clips; the more common alligator clips just don't get a grip on fine wires and transistors leads.

A rotary switch turns the power on and off. I always use a rotary switch in this critical location. A toggle switch could collapse someday, accidentally turning on the circuit. A rotary switch can't possibly do that, and its general health is immediately apparent just by looking at it.

The other two switches are single-pole nonshorting (make after break) rotary switches, and any of several varieties are usable.

When you are finishing up the circuit, leave the transformer heater leads a little loose. You may want to reverse them. Before you finalize things, hook up the tester to a scope, set the scope to very low vertical sensitivity, and see which way the trace goes. It should be a straight line, rising to the right. That is, a positive voltage to the scope's vertical input

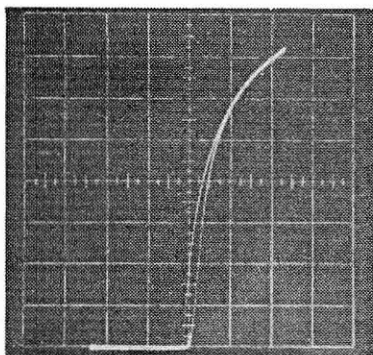


Fig. 7A. Germanium diode characteristics, showing gradual breakdown with increasing reverse voltage and low forward resistance.

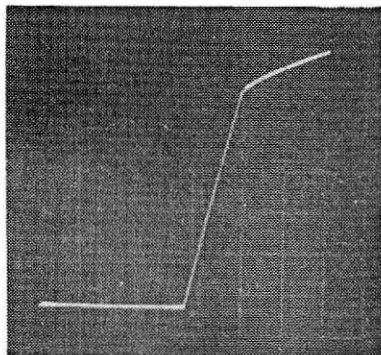


Fig. 7B. Another germanium diode, showing a sharp knee but poor dynamic resistance.

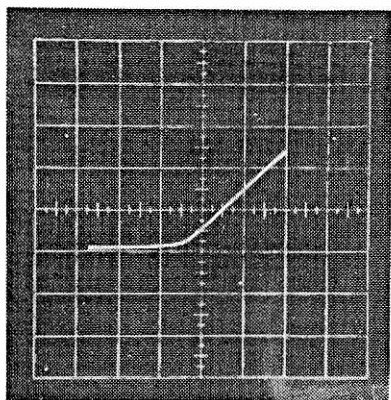


Fig. 8. A germanium diode after overheating. The scope gain is very high, so its diode characteristics are nearly gone.

deflects the spot upwards, and to the horizontal input deflects the spot to the right. Otherwise you may have to redraw the curves shown in the illustrations.

The calibrating diodes go in last. Finish up everything else, and use the tester to choose them. They'll be zeners or other diodes that show good zener characteristics. If you can't find a 150V transformer, compute new resistances for what you have available. Don't use a lower voltage, because some transistors and small diodes show breakdown voltages in the 100V range.

The Calibrating Zeners

If you have a scope with fixed voltage ranges, you probably aren't interested in the calibrating zeners. If not, you need them, but how are you going to find out what their values are?

Perhaps you have some zeners of known characteristics, but the usual 10, 20, or greater tolerance percentages seem rather excessive. If you're familiar with your VTVM, you may have guessed the answer already: use its ability to indicate peak-to-peak ac voltages.

A review of the meter manual should answer any questions that may arise. Inexpensive VTVMs use a peak-reading circuit, with a meter scale labeled for sine-wave readings. We'll just convert those estimated sine-wave figures right back to p-p, by multiplying by 2.82.

Set up the tester and your oscilloscope. Attach your meter ground lead to the tester ground return, and the meter probe to the scope vertical input terminal. Set the VTVM for ac and

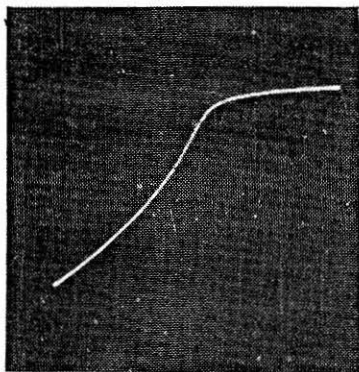


Fig. 9A. BE diode of a germanium transistor. Downward curve indicates a PNP transistor, and rather vague conduction and reverse characteristics suggest high leakage.

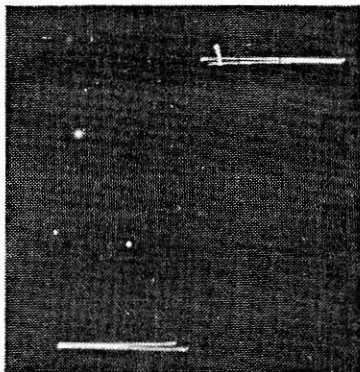


Fig. 9B. BC characteristics of the same transistor. This curve is also downward, and it shows a very sharp conduction and breakdown knee.

start testing diodes. When you come to a diode that has nice sharp corners and flat top and bottom, make an rms reading, convert to p-p, and you have that diode calibrated.

Remember to make your measurements at the same current you will use when calibrating the scope.

Testing Diodes

The quickest way to understand the tester indications is to put a diode in it and then work out the meaning of the different parts of the curve. Repeat with several different diodes.

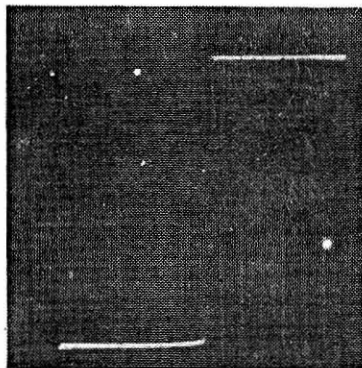


Fig. 10A. It's not obvious here, but this silicon transistor BE diode curve turns upward.

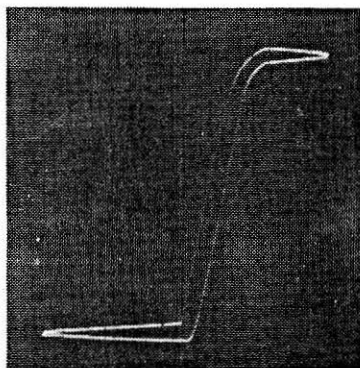


Fig. 10B. BC characteristics of the same transistor.

All bipolar transistors have two inherent diodes. One is the base-emitter diode, and the other is the base-collector diode. The tester checks these diodes one at a time, and it doesn't tell you anything about how the transistor will work. But if one of the diodes is bad, the transistor won't work. And the direction the curve goes indicates whether you have a PNP or an NPN transistor. (See Figs. 9 and 10.)

Why do many diodes show a double line in the vertical parts of the pattern? These lines merge at higher currents but are very distinctly separate for small currents and large diodes. This is phase shift of the applied voltage through the RC network of series resistor and reverse-biased diode capacitance before it goes into breakdown.

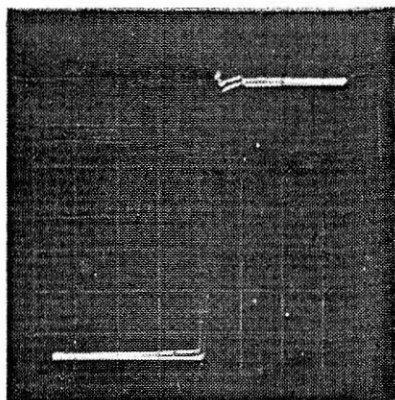


Fig. 11A. A very close look at a perfectly good GE Z4XL6.2 zener diode. It shows some zener noise under 200 microamps, and low dynamic resistance.

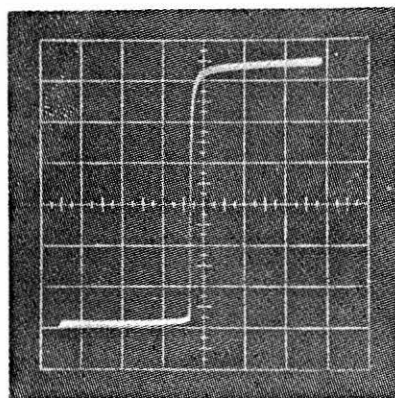


Fig. 11B. BC reverse breakdown curve of an unknown computer-board germanium transistor. This one would make a good low-power zener.

Zener Regulators

Do you have trouble finding zener regulators? The tester will find lots of them, and tell you how they'll work in your circuits.

It turns out that not only specially built silicon diodes will serve as zener regulators, but some unspecial diodes and even germanium transistors! The tester finds the ones that can regulate. Figure 11 shows the base-emitter breakdown characteristics of an unlabeled germanium computer transistor from a discarded printed circuit board.

The tester can supply lots more power than is required to roast a good diode into complete uselessness. Fortunately, this is harder to do than you might think. The power dissipated in the device is the usual product of voltage times current, and since most transistors and diodes break down at under 20V, and can take over 100 mW the average danger line lies around 5 mA. But some transistor may unexpectedly show a base-collector breakdown at 50V or more, and if it's rated at 60 mW you may easily overdo things.

If you're careful to use things only for their intended purposes, you are missing a lot of fun. What can you do with the tester? Try a little neon lamp at low current. Another thought that comes right to mind is that perhaps it can be used in some way to check computer switching cores. You can work up some new ideas. And as you puzzle them out you'll pick up a few pointers enabling you to make better use of this simple but surprisingly handy tester.

Go/No-Go Transistor Checker

by Stephen Popp

A good-bad test on a transistor can be devised on the basis of simple checks which can reveal the existence of a short or open condition between elements.

An ohmmeter reads resistance of a substance by applying a small voltage across the material. If the resistance is low, the applied voltage can force a relatively high amount of current through the unit. The meter indicates the amount of current on the scale even though it is calibrated in ohms.

The instrument will bias the transistor in both directions. If forward bias occurs, large current flows, indicating the resistance is low. Reverse bias will indicate at least a ratio of 20 to 1, if the transistor is normal. If a transistor does not respond as described, it may be considered defective. However, weak units, or those with leakage between elements, might respond satisfactorily. This test is basic and only intended to indicate whether the transistor is completely inoperative. Better quality checks are possible with a number of commercial testers on the market.

Make sure all checks with the tester described are made with the ohmmeter set to the highest resistance range which gives a convenient reading. (Certain types of transistors that are not classed as general purpose may be damaged by the voltage from the ohmmeter.)

The purpose of the tester described in this article is to simplify as well as speed the test in a comfortable and stable position. Whether the transistor is PNP or NPN, simply plug in the unit, connect the ohmmeter to the banana jacks, set the meter to the highest range that will give the convenient reading, set SW2 to the test position (position 1) to zero the meter. Then make transistor checks for E-B in position 2, E-C in position 3, B-C in position 4, and use position 5 for diodes (with the diode in the diode jack, of course).

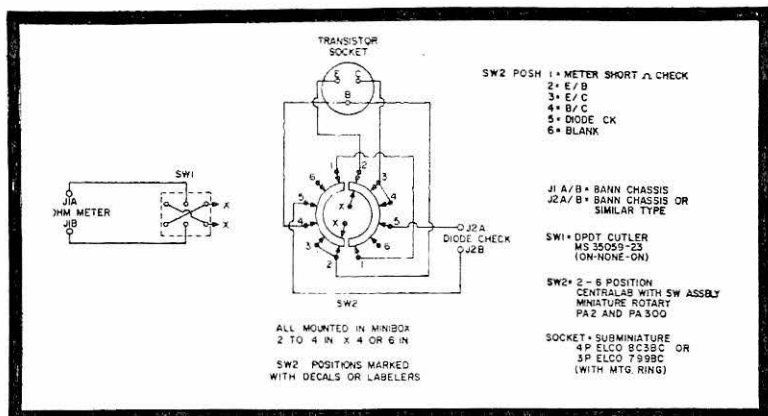


Fig. 1. Schematic diagram of the general purpose transistor checker.

In the diode position, it is also possible to check capacitors for opens and shorts. If it is desired to check components in circuit and if conditions warrant it (one end of component disconnected), simply run a pair of test leads with alligator clips at the diode jacks, leave switch 2 in diode position and use reversing switch 1 to test forward and reverse currents.

Or if desirable, position 6 can be used to run a pair of test leads directly, or perhaps another set of jacks to hook up the test leads.

Scope Readout Transistor-Diode Tester

by Sam Milbourne

In conjunction with an oscilloscope, this file box tester will allow you to check visually the condition of a number of diode and transistor types. The parts list is relatively small and the cost is nominal—the largest item being the 26V transformer. It is simple to build and fascinating to operate.

The circuit is based on furnishing two voltages, phased 90 degrees apart, and connected to the horizontal and vertical scope stages. The base of the transistor under test is connected to ground, the emitter and collector to the respective plates.

Referring to Fig. 1, we see the usual power line connections to the transformer primary. The 26V transformer secondary is supplied to two simple phasing circuits which, when connected to the scope vertical and horizontal amplifiers, results in a circle on the scope screen.

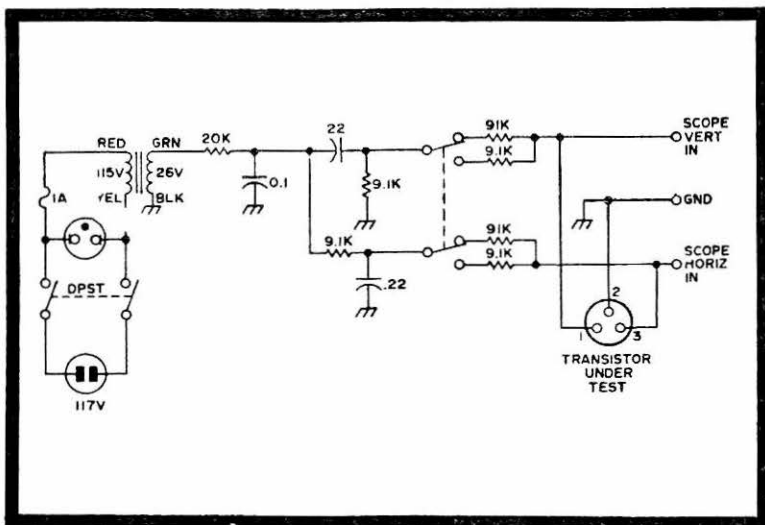


Fig. 1. File box line-quadrature generator type transistor and SCR tester.

DOT INDICATES CENTER OF C.R. TUBE	PNP	NPN	SCR	UNI- JUNCTION	DIODE	BASING
GOOD						PNP OR NPN
B-C SHORT OR E-B2 SHORT						
B-E SHORT OR E-B1 SHORT						SCR
E-C SHORT OR B1-B2 SHORT						
B-C LEAKAGE OR E-B2 LEAKAGE						
B-E LEAKAGE OR E-B1 LEAKAGE						
E-C LEAKAGE OR B1-B2 LEAKAGE						DIODE
E OPEN OR G OPEN						A TO ① C TO ③
C OPEN OR B2 OPEN						
B OPEN OR B1						

Fig. 2. Quadrature generator transistor and diode tester file box.

Note that, to exhibit a perfect circle on the scope screen, both vertical and horizontal amplifiers must be adjusted to an equal deflection on the scope and they must deflect linearly. In fact, the attempt to adjust for a perfect circle is a good test of deflection linearity. If the circle has a "flat" on the right side of the circle, the horizontal amplifier is nonlinear. If there is a flattened portion on the upper side of the circle, there is nonlinearity in the vertical amplifier. Fortunately, some nonlinearity will cause little test result degradation.

The term "quadrature" denotes the finding in square measure of the area of a bounded surface, as of a circle. It also has a meaning of the division of a circular area into four equal sections.

Figure 2 illustrates some of the various possible scope patterns. Note that a good PNP transistor will show a pattern of a quarter "pie" or a quadrant in the lower left portion of the scope screen. A good NPN transistor will show in the upper right quadrant of the scope screen. A good SCR will show a half circle, a unijunction an oval, and a good diode will result in a tilted half circle.

Now, if the collector and the base of a transistor are shorted, only a vertical line will result. If the short is between emitter and base, the pattern is a single horizontal line. Note that the lines radiate from the pattern center.

If the short is between emitter and collector, the single line will radiate on an angle, depending upon whether the transistor is NPN or PNP. A simultaneous short between three transistor elements will show a dot on the scope screen.

Let us suppose that the transistor is neither good nor shorted, but leaky. In this case, the pattern will look like a good transistor except that one leg will be foreshortened (base to collector, base to emitter).

The final group of patterns shows what happens when one of the elements is open. These result in a semicircle covering two of the four quadrants. Basically, what you have left is a diode.

Also included in the scope patterns are the SCRs, unijunctions, and simple diodes. The quadrature generator could also be used for the evaluation of other solid-state devices, but those given in this article should be sufficient to act as a base for additional solid-state types.

A switch allows limiting resistors of 9.1K or 91K to be inserted in the circuit. For most tests the "low power" position should be used.

Assembly

To assemble the unit, first drill four No. 25 holes in the bottom of the file box, positioning each 0.5 in. from a corner. Mount the four feet. Drill and mount the two angles for the panel mounting. Position them about $\frac{1}{8}$ in. down from the

front lip of the box, and at each end of the box. Fasten them with 6-32 screws. After drilling the four mounting holes in the panel, drop the panel onto the brackets and spot the four holes on the brackets. Drill and tap for a 6-32 screw.

The box is now finished except for drawing the schematic on a 3 x 5 file card and pasting on the bottom of the box. A larger 4 x 6 file card could be pasted in the inside lid to show the various patterns as illustrated in Fig. 2.

Now, finish drilling the panel holes. A word of caution: Never take hole diameters from an article. Always check your individual parts, because they sometimes differ. The TV type connector socket hole can be made with a "nibbler," or a series of holes drilled and then filed oblong. Don't forget to mount the insulated washers between the panel and the nuts of the banana jacks. Incidentally, the hole for the banana jack is the diameter of the shoulder washer. The two holes for the transformer depend upon the transformer used. Check these. Mount and wire the parts. You may prefer to mount the resistors and capacitors on tie lugs. Two 5-lug units will suffice. The tie lugs can be mounted through the same screws as used for the transformer.

The 3-hole socket is used so that several sockets can be plugged in. These could include a regular transistor socket, a diode socket, a socket for a power transistor, etc. It was felt that this gave the unit a much greater utility and lessened its obsolescence possibility.

Operation is simple. Connect the unit to the house voltage. Turn the switch on. Connect banana plug leads to the scope's vertical and horizontal inputs as well as to scope ground. Adjust the scope for a circular pattern. Plug the transistor into the semiconductor test socket. Be sure that it is connected correctly. Note the pattern on the screen and refer to the various patterns for interpretation of the pattern. Except for power transistors, the LO-HI power switch can be kept in the LO position.

There is no question but that this tester will show the condition of a transistor better, because it shows, for instance, leakage as a quantitative element. You can see just how much leakage an individual transistor has. By first connecting a good transistor in the tester and then paralleling base to emitter, or base to collector, with a very high resistance resistor, then a lower value, you can see the one side of the

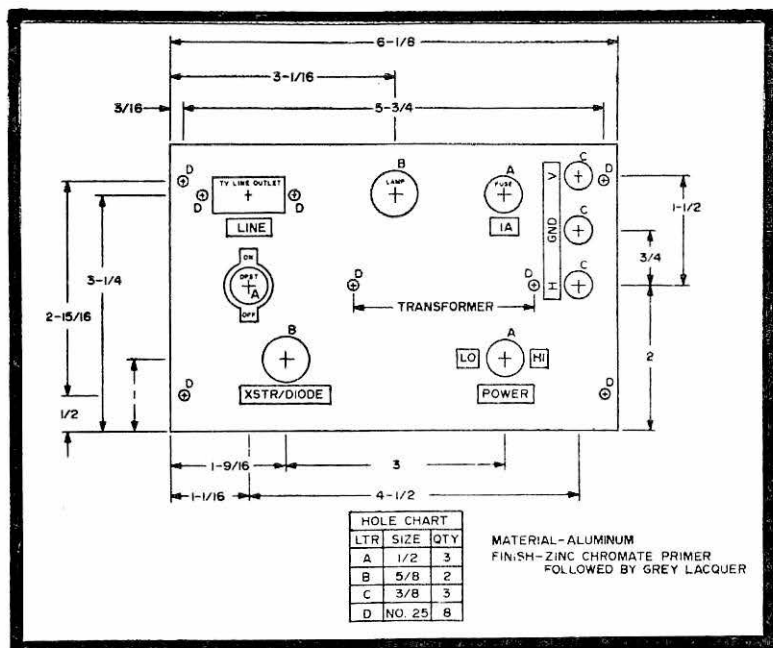


Fig. 3. Layout of file-box panel.

pattern begin to foreshorten. You should be able to use this unit for testing ICs. Of course, some will not be testable, but if you take it circuit-for-circuit, you would be able to test the individual IC elements of many devices.

List of Unmarked Parts

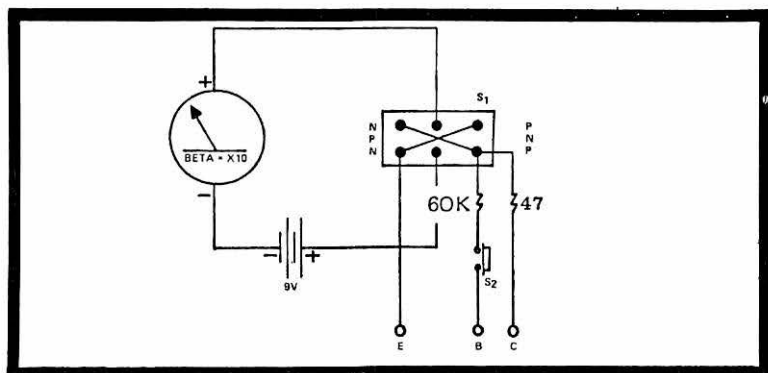
- (1) Fuseholder & 1A 3AG fuse.
- (3) Jack, banana-(2 red, 1 blk.)
- (1) Miniature socket (Amphenol series 78-3S) 3-hole
- (1) Miniature plug (Amphenol Series 71-3SO) 3-prong
- (1) Neon indicator—115V with built-in series resistor
- (1) Power transformer (UTC FT-14 or equiv.) Pri 117 Sec 26V
- (1) Switch, toggle, DPDT.
- (1) Switch, toggle DPST.
- (1) Socket, TV type & mating plug.
- (1) File Box, metal 6¼ x 4½ x 4 (Ohio Art).
- (2) Bracket, angle aluminum—4 x ½ x ½ in. (Reynolds Metal 2406 or equiv.)
- (4) Rubber feet with 6-32 mounting screws and nuts.
- (2) Tie lugs, 5-position.

Transi-Tester

by Lew Christy

This circuit, which I named the "Transi-Test," is designed with simplicity and is very accurate in measuring beta, leakage, and shorts. It will test any NPN or PNP transistor (signal or power). I also find it great in checking silicon or germanium diodes by using the emitter and collector leads to test for shorts and leakage. The Transi-Test is portable (using a 9V battery for its power supply).

Most transistor testers employ a 4-pole switch for polarity, but this one is designed around a DPDT switch, which is easy to find at any parts store. To say the least, all the parts can probably be found in your own junkbox! I used a Premier SPC-23 meter case to give the Transi-Test a professional appearance. The three test leads should extend 6 to 8 in. from the front of the case. For easy connection to small transistors, a "micro" alligator clip should be used (such as the Mueller 34-C). Be sure to use an alligator insulator on the collector lead to prevent the emitter and collector leads from shorting together due to stiff test leads. This will save unnecessary battery failure.



If you do transistor servicing quite frequently, it is advisable to use a toggle switch (S1). The only holes that have to be drilled in the case are for the three test leads, using rubber grommets. The SPC-23 meter case is already prepunched for the meter and two switches, which is why I happened to choose this particular one. Bud Radio also manufactures a case like this one.

After completion of this small project, you can rummage through your junkbox and start identifying those "lost cause" transistors that have been lying dormant. I'm sure you will find the Transi-Test to be a very valuable test instrument on your workbench.

3 Versatile IC Testers

by Richard Factor

As integrated circuits have become more widely used in industry, large numbers of them have been finding their way into the surplus market, often at prices of a few cents each. The cheaper assortments contain many rejects and are frequently unmarked. With transistor assortments, this is not a problem, since transistors generally have three leads, and only a few trials are necessary to find out if they still "transist."

Integrated circuits compound the problem, since they not only have many more leads, but they don't all do the same thing. Figure 1 shows just a few of the many configurations available. With three simple IC testers, you can test and identify virtually all of the ICs you're likely to come across (including those of Fig. 1).

After the sweeping claims above, I should clarify some of the things the testers won't do: They will not rapidly and automatically test all the static and dynamic parameters of ICs. They will not automatically check such complex function units as 256-bit read-only memories and other LSI circuits. They will not test the vast assortment of rf and video amplifiers available. They will give no measurements good to 0.1 percent. But all three can be built for under \$20; so if you don't expect the impossible, you can make up a very handy item to have around.

What the testers will do, and do quite nicely, is test RTL, DTL, and TTL digital logic circuits, decade counters, Nixie drivers, and assorted operational amplifiers and comparators, and tell you whether or not they work.

Testing Philosophy

To test an IC, the simplest thing to do is regard it as a black box. You apply power to it, connect an input to the proper pin, and observe whether the output is as expected. The

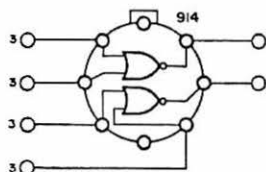
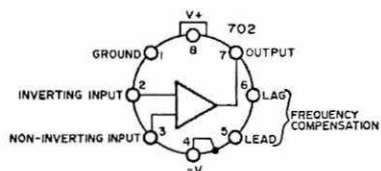
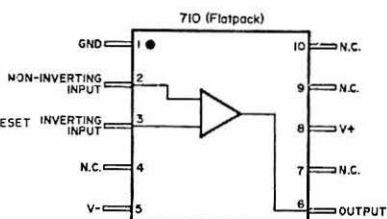
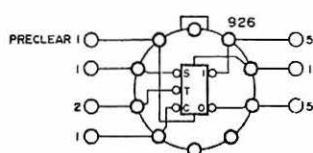
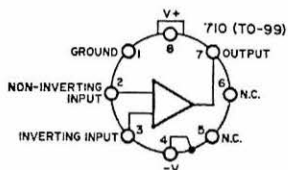
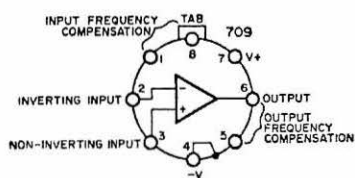
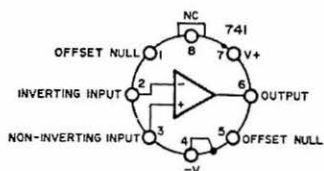
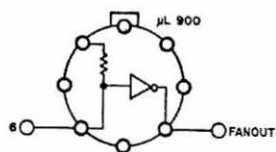


Fig. 1. Connection diagrams for some common ICs. All are shown from top view.

unmarked IC is as much an art as a science. Described here is the procedure I recommend for going through a batch of ICs.

Assume you have latched onto a handful of unmarked TTLs known to belong to the SN7400N series. This family has gates, flip-flops, and assorted complex functions. Since gates are the most common function, it is best to start by looking for them. Connect the patch cords so that pin 7 is grounded, and pin 14 goes to the +5V terminal. One advantage of looking for the gates first is that these power supply connections cannot damage any flip-flops or counters.

It is a very good idea to have the manufacturer's literature handy so that once you identify an IC, you can label it with a number rather than writing a truth table for it, and so you can avoid pitfalls like improper power supply connections. Insert the ICs into the socket and watch the output current of the supply. When it increases (about 5-10 mA), you have reason to believe that the IC is a gate.

The next step is to look for outputs. The easiest way to do this is to connect the scope successively to each pin while holding the tip of the patch cord. Holding the cord puts 60 Hz on the scope input. Inputs have very high impedance, and thus the signal will not disappear when the scope is connected to one. Outputs have either saturated transistor outputs in either state (TTL), or low-resistance pullups (DTL or RTL), and will effectively short out the 60 Hz current picked up by the body. Once an output is identified, connect a pulse input to the other pins and find out which ones give an inverted output. This is now sufficient to identify the IC.

Frequently an IC will be perfectly good except for one input. If it has only a minor defect (one of four gates bad, a defective reset on a flip-flop, or such), you can break off the pin corresponding to the defect. This is much more economical than discarding the unit.

Now that we have identified the gates, let's try some other possibilities. Connecting pin 11 to ground and pin 4 to +5V is appropriate for the SN7473N flip-flop. Again, identify the outputs as above and connect the scope to one of them. Connect the pulse generator to the other pins. If you truly have a flip-flop, you should see the pulse waveform divided down to a square wave at half its frequency.

Similar procedures can be followed for almost any digital IC. Some of the newer functions are sufficiently complex to make a data sheet necessary for testing, or you may never hit

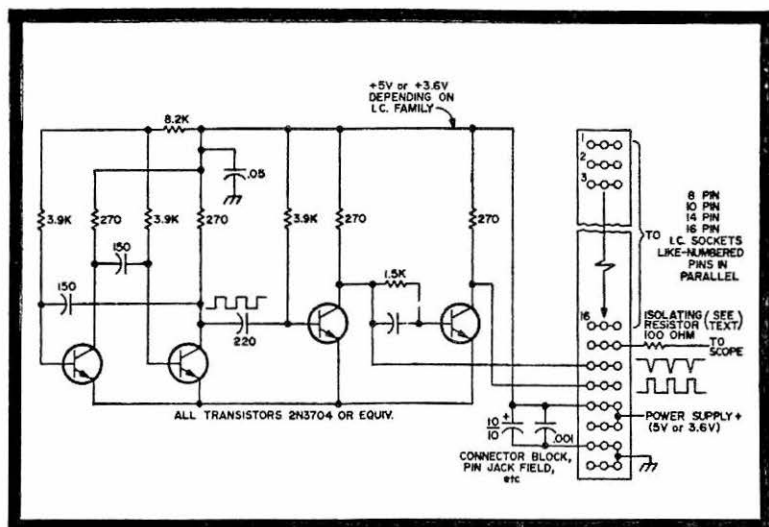


Fig. 2. General purpose digital IC tester.

on an appropriate combination of inputs and outputs. In such a case the digital tester of Fig. 2 can still make valid operational tests, although it will be of little use in identification.

Decade Counters, Nixie Drivers

Counting circuits and readout tube drivers are becoming more popular as their prices decrease. While the SN7490N decade counter can be tested by the above method, it is rather tedious, and the driver cannot be since it is designed to interface with a high-voltage device. To simplify testing of the counter and SN7441N Nixie driver, a special unit was built (Fig. 3) which simulates decade counter operation. Half of an SN7400N (or any other 2-, 3-, or 4-input dual, triple, or quad gate) is used to produce a single pulse each time the SPDT switch is closed. This steps the decade counter, and the Nixie tube is observed for proper operation. Obviously, it is necessary to have a working Nixie driver in the socket when testing the counters, and vice versa.

The 22K resistor in series with the Nixie is for current limiting. This resistor value depends on the B+ supply and the particular tube used. A rule of thumb is to select a resistor which insures that all of each digit is lit up when the corresponding cathode is grounded. The value is not particularly critical.

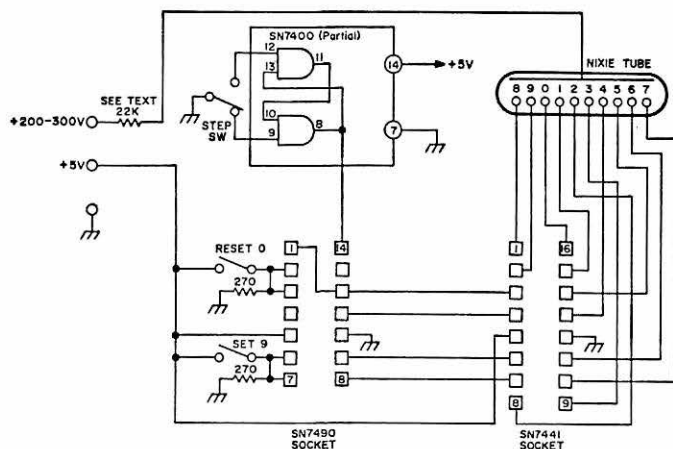


Fig. 3. Decade counter and Nixie driver tester.

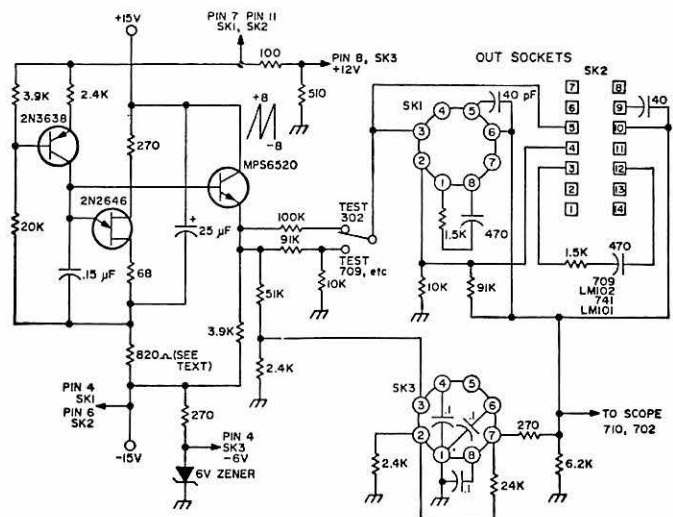


Fig. 4. Linear IC tester.

Linear ICs

Compared to digital ICs, linears are a horse from a different stable. If you have no idea what type you have, you are quite likely to destroy it during the testing procedure. They are designed for a wide variety of positive and negative voltages, and pin connections are quite nonuniform. The most useful type of linear IC is the operational amplifier, or opamp, and the most popular of these is the type 709. They are so popular that the price has plummeted from over \$50 to under \$1 in reasonable quantities, and are available from numerous sources. The linear tester (Fig. 4) was designed primarily for 709 and the 710 comparator. It will also test other opamps, such as the LM101, the 702, the μ A 741, and the LM102 voltage follower. The diagram showing the test-circuit equivalents (Fig. 5) gives the appropriate output waveforms to look for. The tester doesn't test for parameters such as dc offset and open-loop gain, but does provide a go/no-go test.

The unijunction and current-source transistors generate a linear sawtooth of about 16V amplitude. The approximately 820-ohm resistor is adjusted so that the voltage swing is

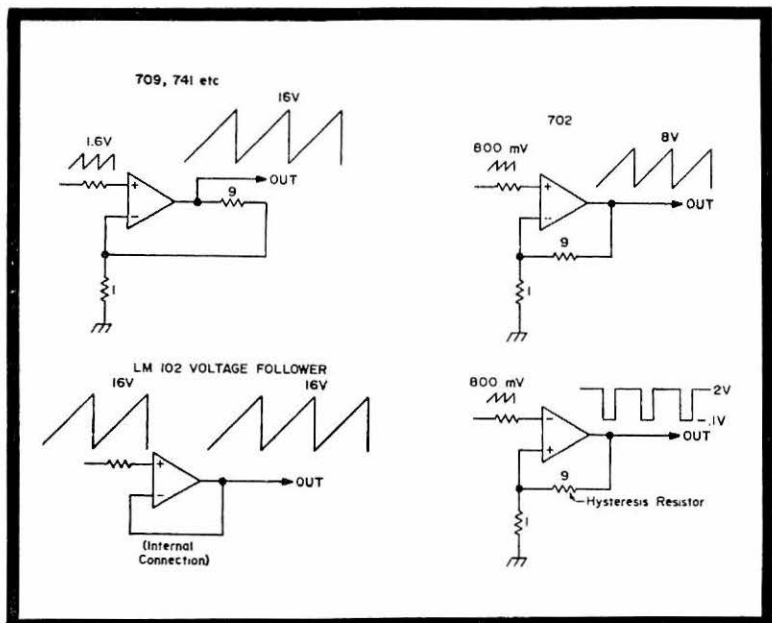


Fig. 5. Simplified test circuit equivalents.

symmetrical about ground when measured at the emitter of the MPS 6520 buffer. This signal is then appropriately attenuated and applied to the device input. The 709 output should be a symmetrical linear sawtooth of 16V amplitude. The 702 output should be similar, but without attenuation. Testing the 709 without attenuation will show its peak-to-peak output swing without delivering enough current to damage the input. A tester switch is used to control the attenuation.

Building the Testers

The diagrams are more or less self-explanatory. The only special component used in any of the testers is the patching arrangement for the digital IC tester. I used some sort of connector block into which small conical pins fit. It had been lying around for so long that I forgot where I got it. If you can't find something like this, you might try an arrangement of terminal strips and alligator clips, or perhaps a field of pin jacks. Also, while it is not shown on the diagrams, it is a good idea to bypass the power supply connections to ground as near to the IC sockets as possible, especially in the linear IC tester.

Unless you're an old pro with ICs, testing them is not as boring a job as it may seem. It is impossible to describe a complete test procedure for all digital ICs, since they fail in as many ways as there are internal components. It is highly instructive to test the ICs with both the pin diagrams and the internal schematics in front of you. It will give you insight into IC operation and a better knowledge of logic functions than can be obtained from the literature. And the money you save from salvaging just a few ICs can equal the cost of the testers.

Measuring Transistor Gain-Bandwidth Product

by Andrew J. Borsa

The usual procedure for determining the rf capabilities of unmarked transistors involves plugging the units into a standard oscillator circuit and then playing with circuit values until oscillations start or the experimenter's patience gives out. Fortunately, there are simpler and more accurate methods of judging a transistor's capabilities. This article will be concerned with the measurement of a transistor's current gain-bandwidth product, usually referred to as its f_t . This is the frequency at which the common-emitter current gain has decreased to a value of unity. This is also one of the most useful parameters to know since a transistor can be operated as an amplifier or oscillator up to and even beyond its f_t . A simple and practical test circuit will be presented and the theory behind its operation will be discussed.

The most common method of determining the f_t involves measuring the high-frequency current gain, h_{fe} , at a point which lies above the beta cutoff frequency, f_B . Beta, or β , usually refers to the low-frequency current gain. A simple graph will help illustrate the meanings of the above parameters. Figure 1 shows what the plot of a UHF transistor's current gain versus frequency might look like. The definition of f_B is the frequency at which the common-emitter current gain is down 3 dB from its low-frequency value (see point A). In this example, it equals 10 MHz. At twice f_B and higher, the current gain falls off at a rate of 6 dB per octave, or 20 dB per decade of frequency. Finally, at a frequency f_t , the current gain has reached a value of unity or 0 dB (see point C). In this example f_t equals 1000 MHz. This -6 dB per octave slope has the property that the product of the current gain and the frequency at any point on the slope equals f_t . For instance, at a frequency of 100 MHz, h_{fe} equals 10 and the product of the two equals 1000 MHz (see point B). This is the measurement

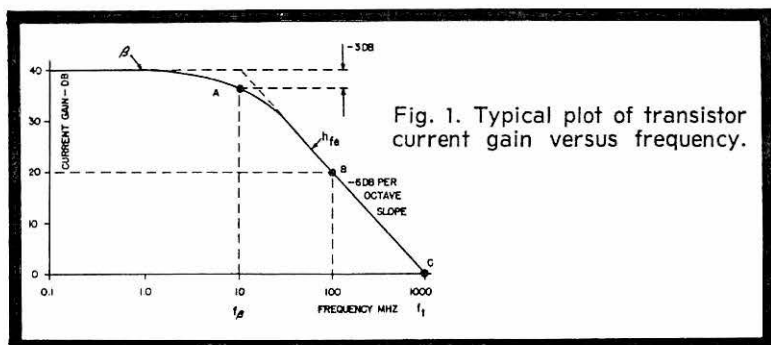


Fig. 1. Typical plot of transistor current gain versus frequency.

we shall have to perform on our unmarked transistor to get a firm idea of its high frequency potentials.

Before proceeding into a description of the test circuit, we must define h_{fe} : it is the small-signal (linear) current transfer ratio from base to collector with the collector and emitter short-circuited and the base open-circuited (for ac only). This condition can be represented by the circuit shown in Fig. 2 where biasing circuitry is omitted. The output current is measured by the ammeter (I_C), which also presents a short circuit load to the collector. The open circuit at the base can be represented by a current source I_S at a frequency f_S which, theoretically, has infinite output impedance. The base current is monitored by another ammeter labeled I_B . Since the emitter is already at ground potential, the circuit satisfies all the requirements imposed on the measurement. It is not, however, very practical since it requires microammeters capable of measuring currents at a few tens of megahertz.

A practical approximation of the above is the circuit shown in Fig. 3. I have designed this particular circuit to sort my personal stock of unmarked goodies into useful regions of frequency. The 10K resistor in the base acts as part of the bias network and also transforms the input voltage V_i into a current to drive the base of the transistor under test. This resistor makes a fairly decent current source if the transistor

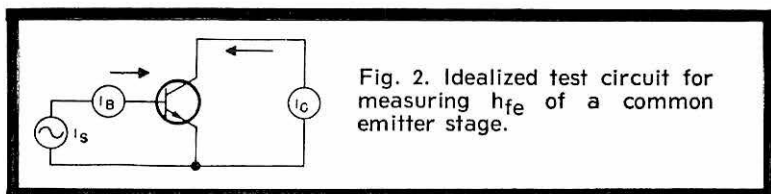


Fig. 2. Idealized test circuit for measuring h_{fe} of a common emitter stage.

input resistance is under 1K. This is a reasonable condition at the dc emitter current level and the frequencies of interest here. The 51-ohm resistor provides a termination for the signal generator used as a source. In the collector circuit, the 68 uH choke acts to pass dc and block ac. The collector ac is almost completely absorbed by the 51-ohm resistor used to approximate the short-circuit load. The load resistor converts this output current into a small voltage which can be measured with an rf millivoltmeter.

Thus the measurement boils down to measuring V_o and V_i and then plugging the values into the following equation:

$$h_{fe} = 200 \times \frac{V_o}{V_i}$$

The 200 represents the conversion factor between the voltage gain and the current gain of the circuit. This constant is equal to R / R_L and was made to be convenient while satisfying the other requirements. The f_t is found by multiplying h_{fe} times the frequency of measurement. It can be seen that the voltage gain will be much less than one—hence the need for a millivoltmeter.

There are a few precautions to be observed in order to use the circuit successfully. The input voltage should be adjusted so that the output is in the range of 10 to 50 mV rms preferably closer to 10 mV. This will insure that the transistor is operating under linear conditions. The frequencies used should be limited to the range of about 5 to 30 MHz. The h_{fe} should be measured at a couple of frequencies and the results examined to insure that the final measurement is being performed on the -6 dB-per-octave slope. The voltmeter ground clip should be attached close to the point of measurement. The supply voltage should be positive for NPN

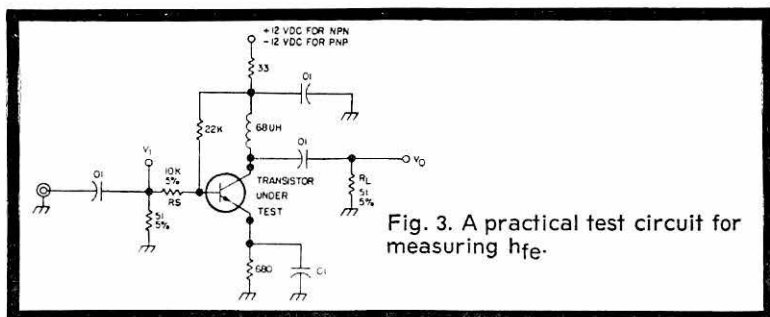


Fig. 3. A practical test circuit for measuring h_{fe} .

transistors. Either silicon or germanium types can be tested in the circuit.

With a 12V supply, the collector current will be about 4.5 mA and the collector-to-emitter voltage will be about 9V. The collector current can be changed at will by decreasing the value of the 680-ohm emitter resistor for a larger current and increasing it for a smaller current. You may want to characterize a transistor at a number of emitter currents, since this has a direct effect on the f_t . Starting at low currents, f_t increases with increasing emitter current. A region will be reached (usually a fairly high current) where the f_t will begin to decrease.

The circuit layout should be as tight as possible. Special care should be taken to keep the leads in the bypass and coupling capacitors as close to zero length as possible. A transistor socket should be used for convenience in testing large numbers of transistors. A copper-clad board would be ideal as the bypass caps can be soldered directly to the ground plane. Standoff terminals can be used at the measurement points for easy access with the voltmeter.

Most experimenters own or have access to signal generators for use as a source of rf. An rf millivoltmeter can be scrounged somewhere with enough searching, or a simple one can be built if you can find a signal generator with an accurate attenuator for calibration. My own voltmeter is homebrew using a couple of crystal diodes and a dc amplifier of FETs and transistors. Lowest range is 10 mV full scale. I find an instrument of this sort indispensable when working with solid-state rf circuits.

Some tests were conducted with transistors having known f_t . The results indicate that the readings will be about 5 to 25 percent low. This error can be attributed to the imperfect current source and short-circuit load used. To make the readings more accurate would require either more sensitive meters or a more complex circuit requiring adjustments for each measurement. This setup fills the bill for making quick tests on a bunch of bargain-basement transistors. For instance, one of the IBM boards in my junkbox yielded a dozen germanium transistors with f_t in the range of 300 to 400 MHz. This piece of information was well worth the time it took to build this test circuit.

Two Low-Cost Beta Testers

by Herb Schoenback

If you have built one or more of the many simple transistor testers described over the years, here is a modification that will give you a direct-reading beta scale. And, if you haven't built one yet, one of the two adapters to be described here should be right up your alley. These adapters are really simple and come as close to being one-evening projects as you are likely to find.

Many years ago while working on a transistorized electronic organ project in my basement, I built a test adapter for use with my VOM (circuit of Fig. 1). This is a little gem which served me well. There are two effective ways of using this type of tester for measuring dc gain, or beta (also known as h_{FE}), and most testers of this type use one of the two.

Method one: To make the beta measurement, simply adjust R_B , starting with maximum resistance, until the voltmeter reads a value equal to half the battery voltage. Neglecting the slight voltage drop from emitter to base, half the battery voltage appears across R_E as read on the meter, and the voltage across R_B will be nearly the same. Under these conditions: $I_C = E / 2R_E$; $I_B = E / 2R_B$; $h_{FE} = I_C / I_B$; then h_{FE} (beta) is equal to R_B / R_E .

By marking the dial of R_B in thousands of ohms, beta readings are obtained from this dial. I built my tester with an

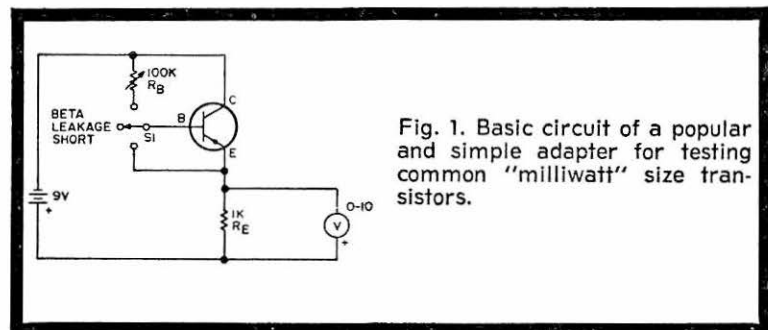


Fig. 1. Basic circuit of a popular and simple adapter for testing common "milliwatt" size transistors.

R_B pot of 50K originally, because in those days transistors seldom had betas over 20. As the state of the art progressed, even cheapie transistors started showing betas close to 100, so I changed R_B to a 100K pot.

Method two: set R_B to 100K or replace with fixed resistor of this value. Next make up a table of values from the formula:

$$\text{beta} = \frac{\text{meter reading in volts}}{\text{battery voltage—meter reading}} \times 100.$$

By using a 10V supply and a 10V meter scale, the table comes out like this:

Meter Reading in Volts	Beta
2	25
3	43
4	67
5	100
6	150
7	230
8	400

At this point I could have made up a special scale but still did not have a spare meter to commit to this service. So I was quite satisfied using the table. For years I went on in this primitive way in an age of digital instrumentation till a thought tremor went through my noggin. One end of the meter scale represents a beta of zero and the other end of the scale represents infinity. But wait! My ohmmeter scale is already marked this way. Only in reverse...and besides, the middles of the scales would never match. Or would they? A check of the formula for calibrating my transistor tester meter showed them to be similar. But by connecting the meter across the transistor instead of across RE, the formula reduced to the same form. Check this for yourself if you like algebra problems.

Construction

Figure 2 is the schematic of an adapter made to plug directly into a Simpson 260 VOM. Make sure the banana plugs are spaced $\frac{5}{8}$ inch to match the Simpson spacing and not the

standard $\frac{3}{4}$ inch. Polarity reversing is done by reversing the battery and the meter polarity switch. But play it safe by keeping the VOM on the 250V range till after the battery is connected. Then, if your hookup is correct, the needle will deflect upscale slightly. Now switch to the 2.5V range and set the 100K pot for full-scale volts (zero ohms). Next insert transistor to be tested in test socket. Check as follows:

Switch Position	Reading	Result
Short	2.5V near zero	Okay Collector shorted or wrong type transistor
Leakage	2.5V 2.2V	very low leakage (normal for silicon)
Beta	2.0V or less	some leakage (normal for germanium)
	Read ohms scale & multiply by 10	excessive leakage

Note that a transistor which shows "shorted" may prove to be the opposite type (NPN or PNP) from what you have set up for, so don't discard it yet.

If you are adapting this circuit for another model VOM, you may have to use different values for R_E or R_B . Keep R_E somewhere near 1000 ohms. Note what your particular ohms

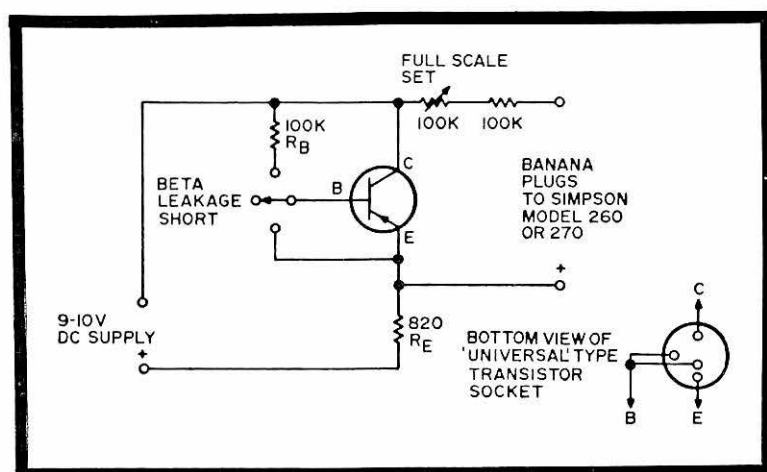
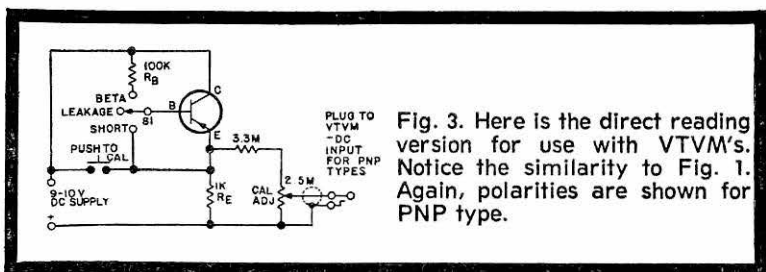


fig. 2. This circuit will provide direct reading of transistor beta right on your VOM ohm scale. Polarities are shown for PNP type.



scale is marked at exactly center, referring to the dc voltage scale. If this center-scale reading is 10, for instance, call this 100 for your transistor beta scale. Then R_B/R_E must be made to equal 100. If the center scale ohm reading is 30, you could make this come out to either 30 or 300 for your beta scale. Just make R_B/R_E equal 30 or 300 to correspond. On Simpson's Model 270, the center of the ohm scale is 12, so I wanted this to be 120 for beta: Therefore, I made R_B/R_E equal 120. (100K/280 is approximately 120 and close enough for this purpose.) In case your VOM does not have a 20,000-ohm-per-volt sensitivity, you will also have to reduce the values of the full-scale set resistors to give smooth control at full scale.

VTVM Version

Figure 3 shows the circuit for use with VTVMs. It's almost the same as the one I started with, but it also will give direct beta readings on the ohms scale. Notice that the meter is back across resistor R_E where it was in Fig. 1. This works for VTVMs which have an ohms scale reading in the same direction as the volt scale. That is, zero ohms is at the left end of scale and infinity at the right. Construction details are up to you for this adapter and for the previously described one. Follow the schematic and they'll work. You can make this one plug into your VTVM if you wish, but on mine I used a short connecting cable to reach my VTVM on its shelf. Operation procedure is also similar to the VOM adapter; however, full scale is adjusted by holding pushbutton and adjusting the 2.5M pot. Set the VTVM to dc volt range, about 3 to 5V full scale. Resistor values shown in Fig. 3 are for VTVMs having 10 (or 100 or 1000) at center of ohms scale. For other center-scale values proceed as before; keep R_E near 1000, but make R_B/R_E equal desired center scale beta value to match your

VTVM. Having set full scale using the pushbutton, plug in or connect the transistor to be tested. Check as follows:

Switch Position	Reading	Result
Short	0 near full scale	Okay Collector shorted
Leakage	0 0-10 percent	very low leakage (normal for silicon)
Beta	10 percent or more Read ohm scale & multiply by 10	some leakage (normal for germanium) excessive leakage

Conclusion

Watch out for some of the epoxy or economy packaged transistors, as several manufacturers are using unconventional basing and the base connection is not always in the middle. Maybe future transistor testers will get to look like tube testers with fifty or so sockets! So better consider providing some extra sockets or at least three binding posts for clip leads. It should be understood that several assumptions have been made in designing these simple testers, and the effects of leakage on the beta reading have been ignored. But nevertheless they are very useful gadgets. So pick the circuit that matches one of your VOMs, scrounge up the parts, and build. If you already have a simple test adapter, just a few changes will give you the "direct reading" feature. Then go through your junkbox and check about fifty of the little unmarked devils. You'll be surprised how fast you can read those betas.

Bibliography

1. Small, Simplified PNP Beta Tester by Benjamin H. Rose, Eatontown, N.J., **Electronic Design**, July 22, 1959
2. A Do-It-Yourself Transistor Tester by E.J. Crossen, Blue Bell, Pa., **EDN** May 1966

File Box Transistor Beta Tester

by Sam Milbourne

The main tests required to determine the adequacy of a transistor are:

1. Determine if NPN or PNP type.
2. Check for short between collector and emitter, collector and base, or base and emitter.
3. Look for open collector, base, or emitter.
4. Check the relative leakage of the transistor.
5. Determine the transistor beta (direct-current gain).
6. Monitor the relative noise level by ear.

Previous design allowed testing of beta to 150. However, higher scale readings were noted and a range switch of plus 100, 200, 300, and 400 was added. By using this equation a fairly accurate tester will result (Fig. 1).

$$\beta = \frac{R4}{2 \times R5}$$

$$R4 = 150 \text{ k}\Omega$$

$$R5 = 500 \Omega$$

Let us assume that we will vary R4 until the dc voltage V_e equals 2V. The resulting resistance of R4 when divided by 1K ($2 \times R5$) will result in the transistor current gain (in kilohms).

For example, after setting V_e at 2V for a specific transistor, by adjusting R4 you may have a total of 130K across R4. This is the direct equivalent of a beta of 130. You will be surprised how much several transistors of the same type will vary in beta. Now, you can determine which are the "hot" ones in a handful of transistors, all of the same type.

Look at Fig. 1 again. This is a simplified circuit. It is a common-emitter type. The two resistors (R1 and R2) form a voltage divider across the 9V power supply. The point V_b will measure 6V to ground. Thus, with the variable resistance set

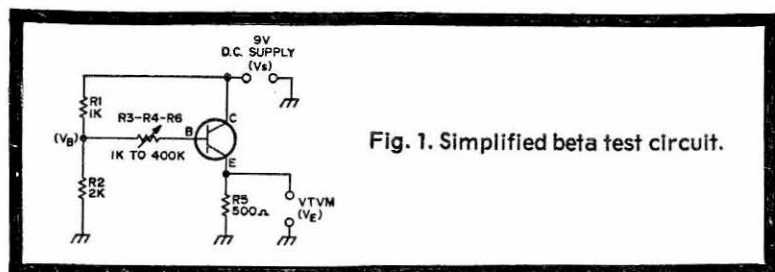


Fig. 1. Simplified beta test circuit.

at minimum, the transistor base-to-ground voltage will be 6V. There will be a drop of 0.3V (germanium) to 0.7V (silicon) across from base to emitter of the transistor. The remainder of the 6V will appear across emitter resistor R5 (approximately 5.5V). By adding the 5.5 and 0.5V we get 6V, or 3V from base to collector.

If we change the variable resistor, we can change the ratio of resistance between the base and emitter resistors. By arbitrarily pegging R5 at 500 ohms, the beta will conform to the formula above. In practice, the variable resistor will be calibrated, with an accurate ohmmeter, to show beta.

Figure 2 shows the actual transistor beta tester. You will see that either a collector-to-base, or a collector-to-emitter short will show a full power supply (9V) reading.

A base-to-emitter short will read 2V if the variable resistor is at minimum. Under this condition, R1 and R5 will then be a voltage divider across 6V, with 4V across R1 and 2V across R5. An open collector will produce the same reading. If either the base or the emitter is open, no voltage will result across R5.

A leakage test is performed by opening the supply voltage at R1. There will always be a small leakage which will result in no reading or a small reading. The lower the leakage, the lower the reading.

Whether the transistor under test is a PNP or an NPN type is easily determined by throwing the toggle switch to the position which results in a forward reading of the VTVM.

Construction

The first thing to do is to collect the necessary parts, as follows:

File box:

- (1) File Box 4 x 6 x 4½ in. Ohio Art Co. or equivalent.

- (2) pcs. $\frac{1}{2} \times \frac{1}{2} \times 1\frac{1}{16} \times 4$ in. of aluminum angle bracket.
(Reynolds Aluminum 2406, old number 161, or equivalent.)
- (4) Rubber feet with 6-32 mounting screws and nuts.
- (1) Panel aluminum, $6\frac{1}{8} \times 3\frac{15}{16} \times .030$ in.
- (8) Machine screws 6-32 x $\frac{1}{4}$ in.

Miscellaneous tools and materials:

Twist drills (Nos. 25 and 35)

6-32 tap and holder.

Fine steel wool.

Alcohol (for panel cleaning, not internal comfort).

Zinc-chromate spray

Lacquer spray, RCA 222627

Tape embosser and tape.

Transistor Beta Tester:

- (1) Switch, 1 Pole, 5 position
- (1) Potentiometer, 150K
- (2) Knobs
- (1) Switch, SPDT
- (1) Switch, DPDT
- (2) Resistors, 1K
- (1 each) Resistors, 500Ω , 2 K, 100K, 200K, 300K, and 400K
- (1) Socket, transistor
- (1) Banana jack, red, with panel insulator
- (3) Banana jack, black, with panel insulator
- (1) Standoff, insulated lug

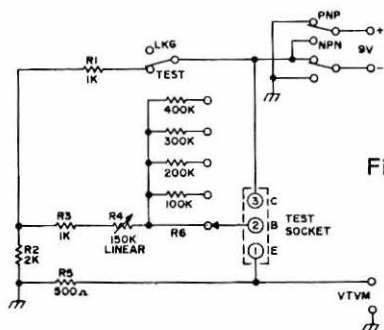


Fig. 2. Transistor beta tester.

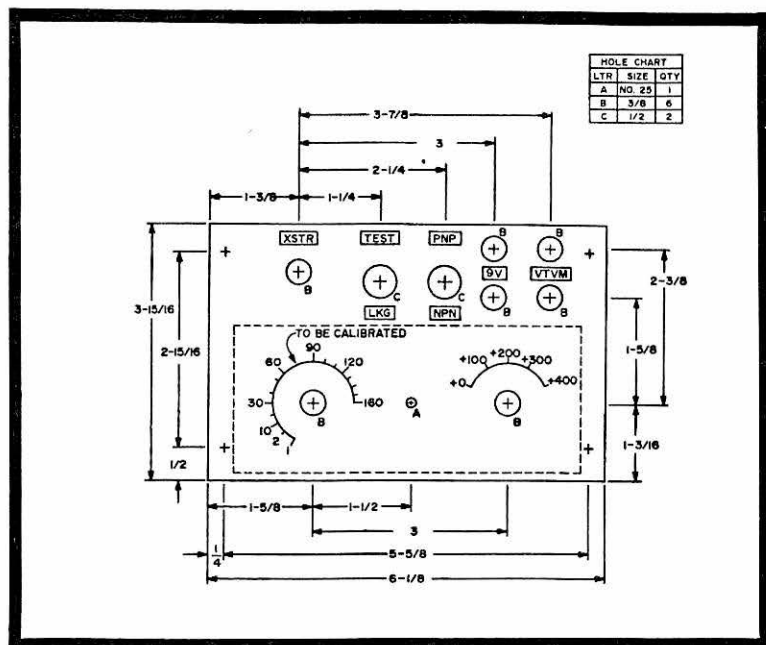


Fig. 3. Front panel dimensions and markings.

Assemble the file box by mounting feet $\frac{1}{2}$ in. in from each corner. Mount the angles inside the box. Position them just below the top edge of the box and at each end. Detailed instructions on this and other construction can be obtained from the previous articles. The holes for the screws in the sides are 2 in. apart and centered.

The tapped screw holes for the panel are positioned 3 in. apart and centered. The holes in the side are made with a No. 25 drill. Those in the bracket tops are made with a No. 35 drill and then tapped using a 6-32 tap.

The panel is laid out and drilled or punched as shown in Fig. 3. Note that the 9V battery is shown as external to the unit. It can be mounted internally, but unless test units are to be used regularly, it is better to keep the battery external.

Before drilling or punching, always check your own parts to see that the required holes agree with those given here.

Prepare the tapes as indicated and affix them as shown in Fig. 3. Take an index card cut to $2\frac{3}{8} \times 4\frac{1}{4}$ in. and lay out as shown in Fig. 3. Use india ink or press-on numbers. The left-hand control will have to be calibrated by placing the card on

the panel, attaching the pot and knob, and then, with an ohmmeter, mark out the kilohms.

Mount all the parts on the panel, including the insulated lug. Wire the unit, swinging the resistors 'tween points as required. Before the tester is finalized, the white card on the panel may be sprayed with clear acrylic. Draw up the schematic and mount it under the unit on the box bottom. Use tape with adhesive on both sides or glue.

Finally, type or cut out the following and paste onto a 4 x 6 card and install it in the file-box top.

QUALITY

1. Set PNP-NPN switch to proper position.
2. Set BETA controls to zero.
3. Set LKG-TEST switch to TEST.
4. Approx. VTVM readings:

Good	5.5V
C-E Short	9.0V
C-B Short	9.0V
B-E Short	2.0V
C Open	2.0V
B Open	0V
E Open	0V

BETA

1. Adjust BETA controls to a VTVM reading of 2.0V.
2. Read beta directly by adding calibrated and switch control reading.

LEAKAGE

1. Reset BETA controls to zero.
2. Set LKG-TEST switch to LKG.
3. Observe VTVM reading.

NOISE CHECK

1. Connect headphones in place of VTVM.
2. Monitor noise level by ear.

$$\text{Beta} = \frac{R4}{2 \times R5} = \frac{R4}{2 \times 500} = R4 \text{ in kilohms}$$

A Transistor Parameter Tracer

by F. Williams

Most transistor manufacturers include on their spec sheets such data as maximum allowable voltage measured from collector to emitter (V_{CE}), maximum allowable collector current (I_C), maximum voltage collector to base (V_{CB}) or base to emitter (V_{BE}), maximum power dissipation and typical beta (h_{FE}) or forward current transfer ratio measured at a given set of parameters. This amounts to the minimum amount of data necessary for basic design purposes, but once the transistor is purchased and a circuit must be constructed, a number of problems suddenly arise. For instance, if the specifications for a gain of 100 are given as $V_{CE}=5V$, $I_C=1\text{ mA}$, $f=1\text{ kHz}$, what change in the value of beta can be expected when $V_{CE} = 12V$, $I_C = 2\text{ mA}$, and $f = 7\text{ MHz}$? Just as important is the missing value of base current (I_B). Since the transistor is a current amplifying device, this parameter is as important for optimum gain as the grid bias in voltage amplifying tube circuitry.

The test unit to be described here is essentially a variable dc transistor power supply with three meters which allow the parameters V_{CE} , I_C , and I_B to be monitored simultaneously. Thus, the designer may vary one or more dc parameters and, by plotting the resulting values on linear graph paper, have a permanent record of the dc curves for each transistor. This is important, due to the fact that most transistors are produced in "batch" quantities and no two of the same type have exactly the same parameters. In addition, the value of dc beta at different bias points may be computed by using the set of dc curves. The value of such design data should be apparent. With the dc parameter information obtained from the transistor tracer, circuitry can be designed and constructed without the usual trial-and-error method. By selecting a suitable bias point on the dc curves for the required value of beta and computing the necessary resistances by Ohm's law,

there will be no question of possible saturation, cutoff, or low gain. An additional feature of the **transistor tracer** is its ability to be utilized as a power supply with variable voltage control and a safe output of 12V at 400 mA or 15V at 300 mA.

The unit shown in the photographs was constructed using a Bud 5 x 4 x 3 in. minibox. As can be seen, no extra panel space is available, and the SPST power switch is mounted on the left side of the box. The size of the meters used determines the space left for the controls when using standard-size miniboxes.

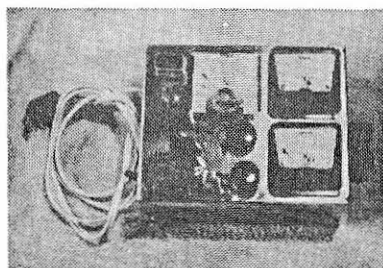
$$\text{beta} = \frac{I_C (\mu\text{A})}{I_B (\mu\text{A})}; V_{CE} = 12 \text{ V}$$

I_C	I_B	beta
1.4 mA	20 μA	70
2.3 mA	40 μA	58
3.5 mA	60 μA	58
4.8 mA	80 μA	60
5.8 mA	100 μA	58
7.2 mA	120 μA	60

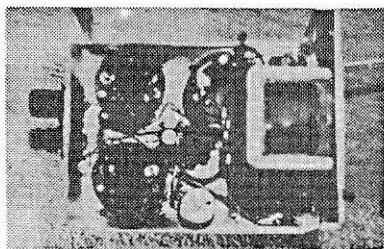
Table I. Beta values taken from Fig. 1.

The neon light was obtained from Olson, order number KB-164, and is supplied with dropping resistor (3 for 99 cents). The transformer shown is a 117/12.6V unit from Olson, order number T-304 (\$1.49). Each diode in the bridge network must have a minimum current rating of 350 mA. The silicon rectifiers are 500 mA units (Olson RE-70).

The transformer is mounted on the right side of the minibox with the wires toward the center of the top panel, and just high enough to allow clearance for the bottom of the box. The four diodes, 2-watt resistor, and pilot light dropping



Overall view of completed transistor parameter tracer.

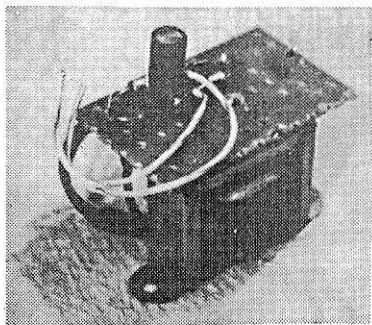


Inside view showing placement of components. (Output terminals and transformer should be switched to alleviate heating of test socket.)

resistor are mounted on a piece of Vectorbord attached to the top of the transformer frame with epoxy glue. Not much space is needed for mounting these components, but overall board dimensions will be determined by the depth of the meters.

Due to the change in parameters which occurs when a transistor is subjected to temperature variations, the transistor socket should be mounted on the opposite side of the box from the transformer. A number of $\frac{1}{4}$ in. holes should be drilled above the transformer on the side of the minibox and on both sides of the other section of the enclosure, just below the transformer, to allow air circulation. In cases where the transformer produces excess heat, it will be necessary to place a heat shield around the socket. The first filter capacitor is soldered across the bridge and is supported by its own leads. Two electrolytics are not necessary, but the added filter capacitor is desirable. The 25K control is a 5-watt miniature unit made by Mallory (VW25K). It is smaller than the average potentiometer, but well within its power rating.

The value of the bias control is not critical, with the exception that too low a value will draw unnecessary current, requiring a larger rheostat. Also, since no series meter resistor is used, the medium setting of this control should provide meter protection in the event that the transistor under



Power supply components are mounted on small piece of Vectorbord glued to transformer.

test is shorted. In order to be able to monitor voltage and current when the tracer is utilized as a power supply, the voltmeter is connected across the circuit at all times. When the function switch is in the 12V/400 mA position, the 0-50 mA meter is shunted with constant-resistance wire (R_1) of a value which allows the meter to measure 0-500 mA, or 10 times its normal scale. The value of this shunt resistance is determined by the formula $R = R_m / n - 1$, where R is the necessary shunt resistance, R_m is the internal resistance of the meter, and n is the factor by which the original scale is to be multiplied. Thus, with a meter resistance of 2 ohms, the necessary shunt resistance is $R = 2/10 - 1 = 0.22$ ohm. If constant-resistance wire having a resistance of 2 ohms per foot were used, $2/12 = 0.22 / \text{length} = 2.64$ in. of this wire would be needed for the

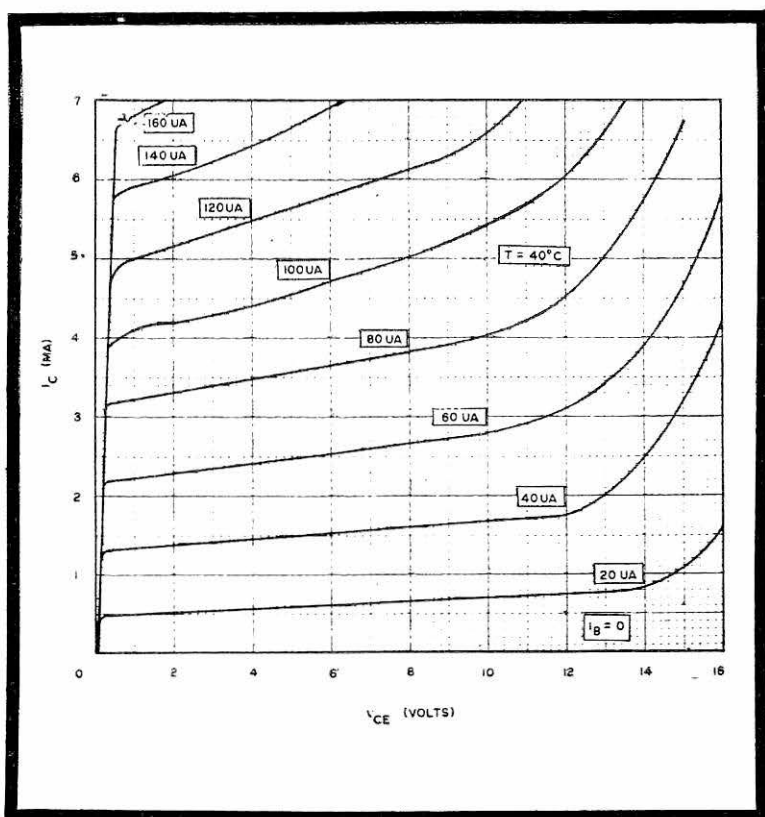


Fig. 1. Dc curves of 2N918 transistor obtained with the transistor parameter tracer.

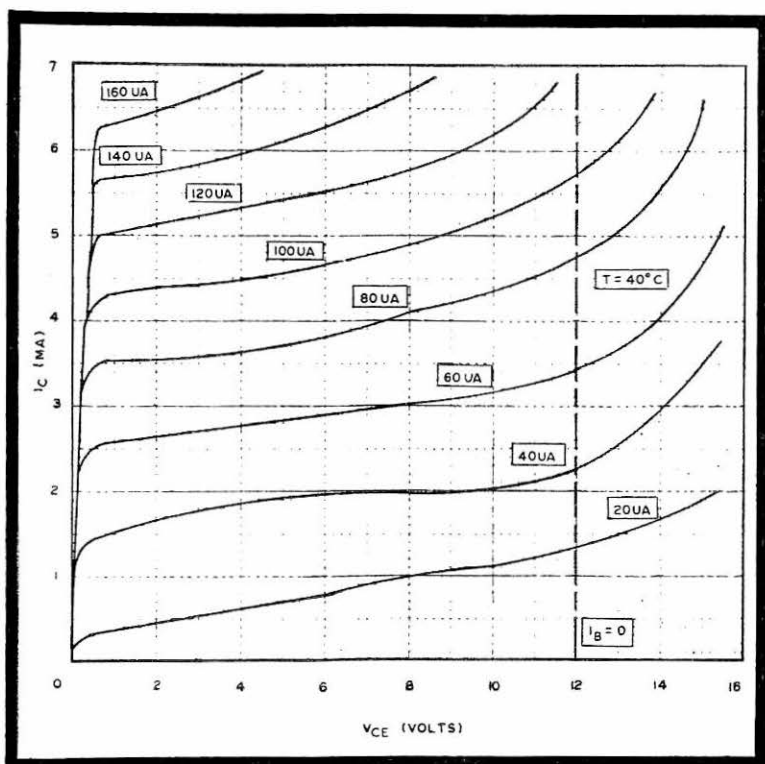
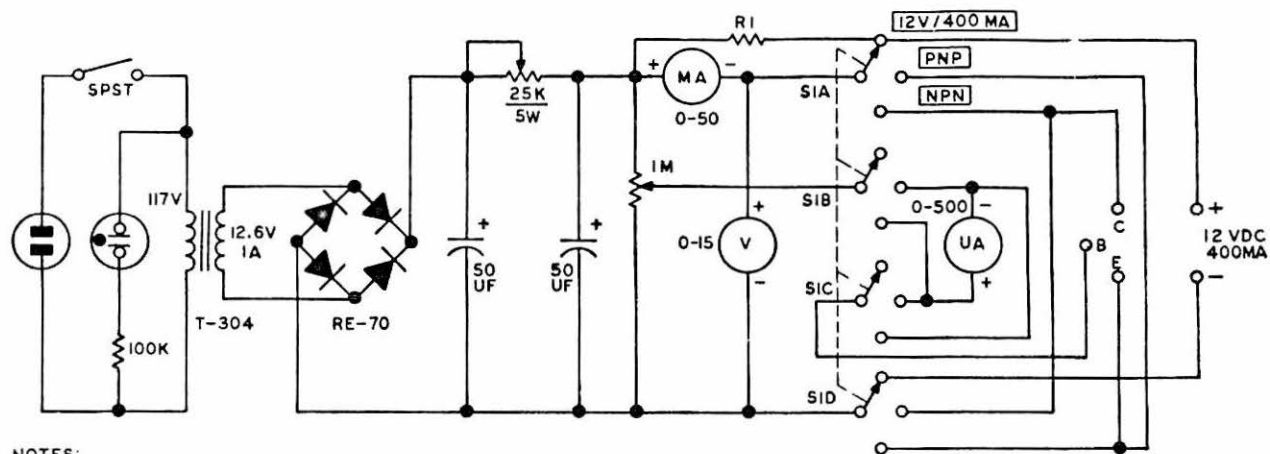


Fig. 2. Dc curves of 2N918 transistor from manufacturer's spec sheet.

shunt. It is best to cut the length slightly longer to allow for soldering, then adjust by cutting about $\frac{1}{8}$ inch at a time from the length while monitoring the output with a variable 5-watt load connected in series with a reference milliammeter. With a variable load between 24 and 120 ohms, the meter reading from 100 to 400 mA can be checked. An alternate method, not requiring a reference meter, is the use of composition resistors, arranged in series or parallel, to give a value of 30 ohms with a power dissipation of 5 watts. With this load connected across the output, a 12V reading on the voltmeter should give a reading of 400 mA on the milliammeter when the shunt is the correct length. Keep in mind that the power rating of the supply is 5 watts, limited by the 25K control, and any reading over 12V at 400 mA will be close to exceeding this value, causing possible damage to the rheostat. All meters should be calibrated with the help of a reference meter and the zero-set screws made fast with a drop of clear nail polish



NOTES:

1. UNLESS OTHERWISE INDICATED
RESISTANCE IS IN OHMS.
2. S1 = 4-POLE, 3-POSITION SWITCH.

Fig. 3. Schematic of the transistor parameter tracer. See text for component description.

or glue. The output terminals to which the **transistor tracer** supplies power when the function switch is in the 12V/400 mA position, are H. H. Smith 269RB.

Operation

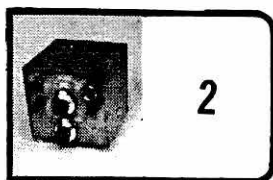
A VOM should be used to check out wiring and to assure that the function switch has been connected with the correct polarities (NPN, PNP) in reference to the transistor socket pins. To preclude applying too high a voltage to the transistor under test and to protect the meter in case of an inner transistor short, the V_{CE}/I_C control should be set to maximum resistance before applying power. Potentiometer I_B should be set at midrange for similar reasons. In addition, since transistor breakdown from possible transients can occur when inserting a transistor into the socket with the power on, the line switch should remain off until the transistor to be tested is inserted and the controls are set as above.

After setting the function switch on the polarity of the transistor to be tested, inserting the transistor into the test socket, and adjusting the controls as outlined above, power may be applied. The V_{CE}/I_C and I_B controls are interacting; that is, changing the setting of one will affect the meter reading controlled by the other. Therefore, it is possible to obtain a dc curve within the limits of the meters and the transistor under test. By advancing the V_{CE}/I_C control until a reading is shown on the milliammeter, the first set of values is obtained. Varying the I_B control will show whether the base is drawing current or if it is cut off. Continual advancing of the V_{CE}/I_C control in convenient steps will give additional sets of values, as advancing the I_B control will give different levels of base current. By readjusting both controls for each set of values, a constant base-current curve at difference values of V_{CE} and I_C can be noted.

These values of V_{CE} , I_C , and I_B for each setting can be transformed into a dc curve for the transistor under test by utilizing linear graph paper. Figure 1 shows such a dc curve for a 2N918 transistor, plotted from values obtained with the transistor tracer. Figure 2 shows the dc curves included on the manufacturer's spec sheet for this transistor. The value of beta, or the gain which can be expected from the transistor under test, can be computed at any point along the dc curves. Since beta is equal to $I_C(\mu A)/I_B(\mu A)$ for any constant value

of V_{CE} , beta may be determined for any corresponding values of I_C , I_B along the chosen vertical V_{CE} axis. Table 1 shows the computed values of beta taken along the $V_{CE}=12V$ axis for the 2N918 transistor. The values of beta obtained with the transistor tracer are valid only for the common-emitter configuration. Naturally, the available gain will not be as great when the transistor is used in the common-base configuration, and cannot be expected to provide any gain when utilized in the common-collector configuration.

An Impedance Multiplier for VOMs by Sam Creason



The typical VOM is inexpensive, rugged, and independent of the ac mains. However, it has a disadvantage in that it can't be used to measure voltages in relatively high-impedance circuits without circuit loading and loss in accuracy. Consider the circuit in Fig. 1. A VOM is being used to measure the voltage drop across R_2 . A typical VOM has an input impedance of 20,000 ohms per volt; this means that the input impedance of the VOM, in ohms, is 20,000 times the full-scale voltage.

On the 10V scale, for example, the input impedance is 200K. If R_1 and R_2 are relatively small, say 2K, then the effect of shunting R_2 with the VOM will be small. In Fig. 1, if the applied voltage is 20V, then the VOM will read approximately 9.9V. On the other hand, if R_1 and R_2 are 2M, then the VOM will read approximately 2V! Clearly, one solution to the problem is to buy an EVM with an input impedance of 22M or so. A less expensive solution is to build the impedance multiplier described in this article.

The schematic of the unit, shown in Fig. 2, consists of a voltage divider which presents a 25M impedance to the voltage being measured, and an operational-amplifier unity-gain voltage follower.

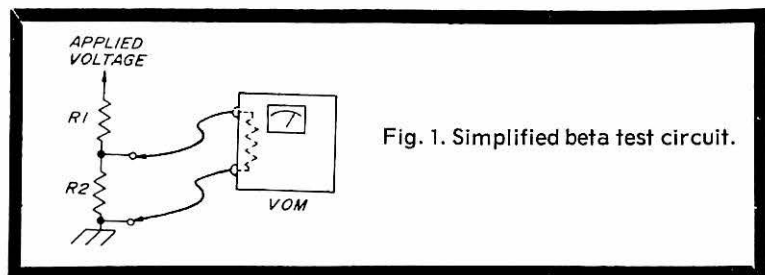


Fig. 1. Simplified beta test circuit.

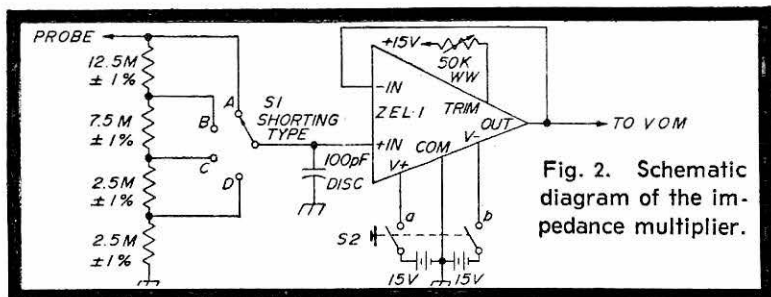


Fig. 2. Schematic diagram of the impedance multiplier.

The voltage follower has characteristics which make it ideal for the task at hand. Its input impedance is several hundred megohms, so that it does not degrade the accuracy of the voltage divider. Its output impedance is less than an ohm and it can supply up to 5 mA (or more, depending on the amplifier used), so it is virtually unaffected by the VOM. Finally, as its name implies, its output voltage is (for all practical purposes) the same as its input voltage.

For the service specialist looking at his first operational amplifier circuit, the following may be helpful.

An operational amplifier is a linear, high-gain, direct-coupled amplifier, usually provided with a differential input, but with its output referenced to ground. The usual symbol is shown in Fig. 3A. If a small voltage (a millivolt or more) is applied, the output voltage will swing to one or the other of its limits (typically $\pm 10V$). Only for voltages less than about 0.1 mV (for the ZEL-1) will the output voltage not be at one of its limits.

The polarity of the output voltage depends directly on the polarity of the input voltage. That is, with the positive lead of the source connected to the positive input of the amplifier, the output voltage will be positive, and vice versa. Further, instead of connecting one voltage source across both input terminals, a separate source can be connected to each input, with the second lead of each source connected to ground. In this case it is the difference of the two input voltages which appears across the amplifier input. The key to the operation of the follower is that one of these voltages is the one we wish to measure while the other is provided by the amplifier.

A simplified schematic of the voltage follower is shown in Fig. 3B. Consider what happens if, say, +5V is applied at E_{in} . If E_{out} happens to be at some value other than very nearly +5V when the input voltage is applied, then a large voltage

appears across the amplifier input and the amplifier is driven hard toward one of its limits. But as the output swings past +5V, as it must because of the polarity relationships enumerated above, the polarity of the input signal is reversed, which means that E_{out} will then start to swing in the opposite direction. Because the gain of the amplifier is large and the response time short, the voltage difference across the input terminals is quickly driven to a very small value and the circuit obeys the relation: $E_{out} = E_{in}$.

The voltage follower is only one of a wide variety of operational amplifier circuits. The interested reader is referred to the publications listed in the bibliography.

The circuit of the voltage follower is well known and time proved. For the builder who is starting from scratch, two amplifiers can be recommended. First is the ZEL-1, the type specified in Fig. 2, which is available for \$11 from Zeltex, Inc., Concord, Calif. While the ZEL-1 is expensive, it does tend to be forgiving about having its output shorted to ground and the like. For the less cautious, the uA709 is available at \$2 from Poly-Paks, Lynnfield, Mass. 01940. It is not nearly so forgiving. A circuit which accommodates the uA709 is shown in Fig. 4.

Other than the fixed value components, the main difference in the circuit requirements of the two amplifiers is the 50K trimmer pot which is used with the ZEL-1. The pot is used to adjust the follower output to exactly zero when the probe to the voltage divider is shorted to ground. In some applications, the absence of such a control in the uA709 circuit would be a handicap. However, an error of only a millivolt or two is likely to result in this application. If a ZEL-1 amplifier is used, the pot may be replaced by a fixed resistor once the correct value has been experimentally determined.

The accuracy of readings made with the impedance multiplier in use will depend in part on the accuracy of the VOM involved and in part on the accuracy of the resistors used in the voltage divider. Since the garden-variety VOM has an

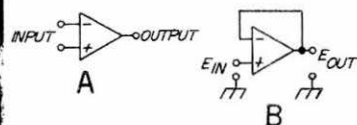


Fig. 3. The operational amplifier symbol and voltage follower circuit.

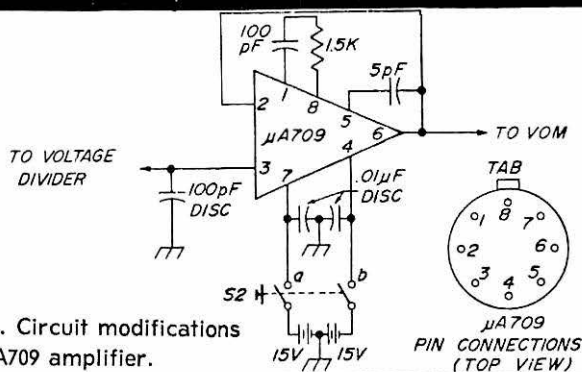


Fig. 4. Circuit modifications for $\mu A709$ amplifier.

error tolerance of no better than ± 2 percent use of better than 1-percent-tolerance resistors seems unwarranted.

ADPST switch should be provided as shown, in the interest of long battery life. Also, battery voltage should be checked frequently, since the output voltage swing capability of the amplifier depends markedly on supply voltage.

Physical layout is not at all important. The device will fit into a small minibox which can be provided with male plugs so that it can be plugged into the VOM in place of the probe leads.

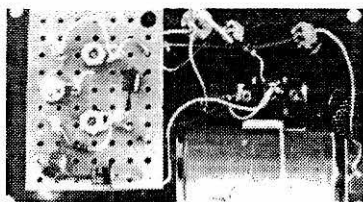
Operation of the impedance multiplier is straightforward. With the VOM switched to its 10V range, a full-scale range of 10, 20, 50, or 100V is provided when the range switch (S1) is in position A, B, C, or D, respectively. The unit may also be used with the VOM switched to a more sensitive range. As before, the voltage which appears at the output of the amplifier is the same as that at the input of the amplifier, but the full-scale capability of the combination is reduced. For example, with the VOM switched to a 2V range and the voltage divider switched to position D, the voltage to be measured must be less than 20V or the VOM will go off scale.

The impedance multiplier may be used to make either dc or low frequency as (audio) measurements. The only restriction is that not more than 10V may be applied to the input of the voltage follower.

Bibliography

Applications Manual for Operational Amplifiers, Philbrick—Nexus Research, Dedham, Mass. 02026.
RCA Linear Integrated Circuit Fundamentals, Radio Corp. of America, Harrison, N. J.

The Low-Ohm Meter by A. Schecner



Did you ever try to get a good resistance reading on a speaker voice coil? Or an automobile ignition ballast resistor? Or a pilot light bulb, length of coax, relay contact, loading coil, transformer winding, etc.? If you have, then you've found that most ohmmeters don't have a really low resistance scale; or if they do, the zero setting is unreliable and the meter scale inadequate. After years of annoyance from this problem I finally decided that a low-value ohmmeter would be a handy device to have around. In fact, applications for this meter just seem to suggest themselves. Why bother building a new version of an old instrument and not incorporate new innovations? So I came up with these requirements:

No. zeroing knob—just a “set it and forget it” calibration control.

Linear scale reading from zero to a fixed value, rather than to infinity. What good is infinity to an ohmmeter, besides making the upper 25 percent or so of the scale relatively useless?

Solid terminal connectors rather than wires with probes (optional). This would prevent poor contacts in the circuit, leading to error.

The finished version uses one D size cell and has two scales: zero to 10 ohms, and zero to 1 ohm. A “test” switch (momentary pushbutton) is used because of the high current requirement of the circuit. Battery life is conserved in this way.

Theory of operation

The circuit consists of a constant-current generator (Q1) to provide a known current through the test resistance. The voltage drop across this resistance (100 mV maximum) is read on a meter whose internal resistance is much higher than a test resistance of 10 ohms. Therefore, the meter does not load the circuit. (See Fig. 1.)

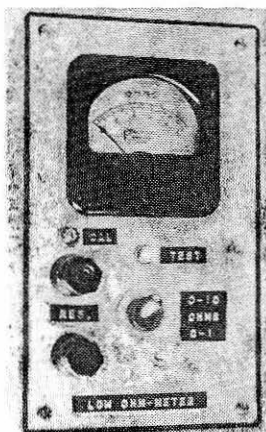
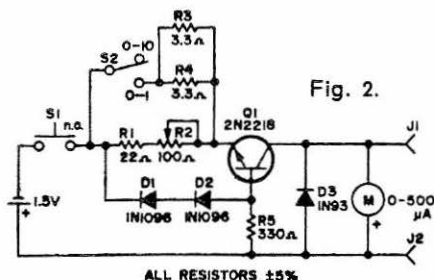


Fig. 1. Low-ohm meter circuit.



A bias for Q1 is established by diodes D1 and D2 and resistors R1, R2, R3, R4, and R5. Use of the diodes holds the bias level constant despite nominal decay of battery voltage. Diode D3 prevents severe overload of the meter in the absence of a test resistance. In case the test button is pressed, the meter will overload, but not much, thanks to D3.

My meter was obtained when I scrapped a Heath grid-dipper after buying a solid-state model. The meter requirements are 500 μ A full scale, 200 ohms resistance. A substitute may be constructed by using a more sensitive meter with a shunt, so long as the result is 500 μ A, 200 ohms.

Construction

Layout is not critical, but solder connections must be solid and medium bus wire must be used. The battery connector must make tight connection with the battery. Check internal resistance by shorting the test terminals with heavy wire. Pressing the test button should give a reading of zero.

Transistor Q1 may be replaced by any one of a number of high-beta NPN types. Try what you have around and see if it works. R2 may be used to balance slight differences if another transistor is used. Calibrate by testing a precision 10-ohm resistor (10 ohm scale) and setting the calibration control for a full-scale reading. The other scale should follow automatically.

Photos 1 and 2 show the meter built in a Bakelite box with aluminum panel.

DC VTVM

by Jim Ashe

Can you build a better dc VTVM than you can buy? Well, I suppose that depends. But if you've never tried, why don't you at least breadboard this circuit? You may find that dc amplifiers and meter circuits are not so complicated after all, if you have some good ideas to work from. And here they are!

The finished instrument reflects my own experience in test and development work. The voltage ranges increase by factors of 2 or 2.5, from 1V full-scale (through probe) to 500V full-scale. Direct input sensitivity is 0.1V to 50V, and has proved very useful, although you have to be careful with it. The bipolar scale eliminates switching, an annoyance around transistor circuits which often have some of each polarity none too clearly marked. The test probe has three resistors totaling 18 megohms near its tip. This minimizes disturbance of circuits, even at rf. And an appropriate bypass capacitor eliminates noise transmission from the instrument back to the circuit under test.

Although the circuit will get by with almost any meter movement of a milliampere or less, long scales are rare. For instance, the nice Lafayette meters priced around \$4.95 have a 1-inch scale. But Selectronics is selling a meter with a 6-inch scale for \$4.50. That's large enough for hand manufacture of a new scale, and you have the option of making the job easier by going full-scale and adding a reversing switch.

Circuit Details

The instrument circuit breaks down naturally into four parts. They are the power supply, the input divider, the dc amplifier, and the meter driver. If you cannot exactly duplicate the circuit described, reread the description of the parts you're going to change, and then start breadboarding.

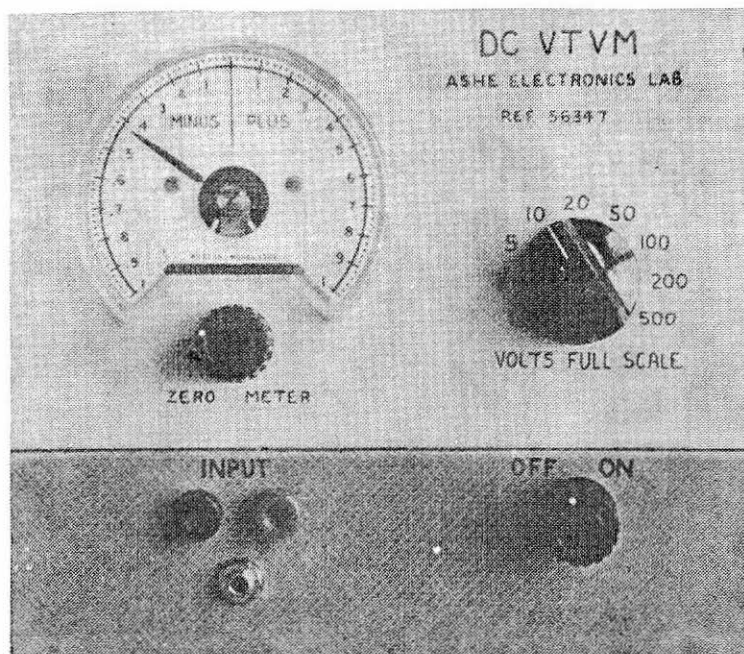


Fig. 1. Front view of dc VTVM. It exhibits 18 megohms input impedance and has nine full scale voltage ranges from one to 500 volts dc.

Because the two OB2 VT tubes fix the critical voltages, there is no need to duplicate the supply section. Any transformer which will give you a filtered dc output of 250 to 350V at 20 mA or more and 6.3V ac at roughly 0.6A will be adequate. If you have any doubts about the transformer, make up a breadboard and load it to these specs for a few hours. It shouldn't get too hot to touch. When assembling the instrument, check the VR current for a minimum of 5 mA under operating conditions. I've added a neon lamp's stabilized bias to the heater leads because this is said to improve tube life, and a small series resistor drops the heater voltage to within the manufacturer's specs.

Instrument accuracy is established by the input voltage divider. But not all parts of the divider are equally critical! If the 18 megohms in the probe is in error, this constant inaccuracy can be corrected for all ranges by adjusting the calibration control. The nine resistors in the voltage divider string are the most critical, and it turns out they are all values

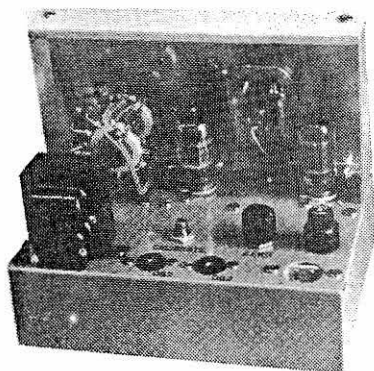


Fig. 2. Back view of dc VTVM. In this shot the OB2's were pulled out for better view. The lip at top of the panel makes a convenient handle.

you can easily measure on an inexpensive impedance bridge. I bashfully admit I planned it that way. When building, proceed in this order: Find accurate resistors for the voltage divider. Then use three good precision resistors for the probe. Calibrate through the probe. Then choose a resistor for the direct input, near 180K which gives correct readings (at 10x sensitivity).

Your nine accurate resistors may be a problem. I selected ordinary half-watt composition resistors on my Heathkit impedance bridge, in some cases putting a small one in series with a large one, so as to hit all values accurately. I used heatsinks for soldering to avoid calibration changes. Perhaps the resistors will drift with time and need to be corrected later. You might prefer highly stable 1-percent resistors, choosing values close to those specified and avoiding cumulative error as you pass up the string by selecting values on opposite sides of true figures.

A properly designed instrument will not introduce hum and noise into the circuit being studied. If the meter input line is acquiring some ac from a nearby power lead, this may be introduced into the probe and go on from there. But a large bypass capacitor keeps this line at signal ground, and it also slows meter needle response. My meter requires about 1 second to come to a reading.

Transistors are very nice for guaranteeing vacuum tube operating points. Not out of place at all, and since only dc conditions are important, an inexpensive transistor will do a fine job. If you've had experience with industrial and computer circuits, you'll see why I call this arrangement "bobtail

bias." The transistor fixes the current through its emitter resistor by guaranteeing the voltage across it, and this in turn determines the operating point of the 12AU7. The transistor base voltage is fixed by the divider across the zener diode. It turns out the zener is necessary for good stability, since the OB2 regulated dc voltage is still pretty drifts. Choose the upper resistor for 3.4V across the 470-ohm emitter resistor. The tube cathode and anode voltages should come out right with no further effort.

The vacuum-tube circuit is known as a "difference amplifier." It is used because of its relative stability; drift in one half is compensated by roughly equal drift in the other half. The circuit compares voltages applied to the grids, amplifying the difference. For instance, if both grids go positive, the cathode does too. Tube current remains constant, and there is no output. But if one grid goes positive and the other does not, the tube currents are unbalanced and there is a net output. This is why you cannot eliminate the apparently superfluous resistor and capacitor to ground from pin 7. There is some grid current and noise pickup, which only balances out if both grids see the same view to ground.

You may find some advantage in selecting the amplifier tube for stability and minimum grid current. The coarse zero control is large enough to compensate for more than the usual variations in tube properties, but some 12AU7As show better stability than others. Grid current in my meter produces about a 2 percent drift in going to the lowest range, which is not inconvenient, but a selected tube could probably improve on this.

Since there is no negative supply voltage, and a pot in the cathode circuit would spoil the nice properties of the difference amplifier, the meter zero control is a variable resistance in one anode circuit. If the anode voltage is too high, we just put in a little more resistance to bring it down. Works fine. The 12AU7As are quite variable in the amount of correction required, so one large resistor is placed in the chassis, and a small one in the panel for vernier corrections.

The Selectronics meter has about a 1000-ohm coil, and requires 500 uA for full-scale deflection. This is a heavy load for a small, low-current vacuum tube. So I've added a cathode follower to drive the meter. This enables the difference amplifier to operate at full gain of about 10. Because the cathode follower is heavily loaded, overall voltage gain is about 3.

The electrical connections to the meter are in the insulated wire extending from the back, and the two studs also

extending from the back. If you wire the circuit as I've shown in the schematic, the lead goes to the calibration pot and to pin 3; the studs to pin 8 of the 12AU7A cathode follower. This gives upscale deflection for positive voltages. The wire lead is the meter's positive terminal.

A small precaution is required to eliminate a front panel shock hazard. Cut or break off the two-fingered zeroing extension from the meter face into the movement. It's nickel-plated soft brass. You find this inside the cover, not the movement. Careful, the zeroing screw is mounted in thin plastic! This connection should be broken because the meter movement operates at 12AU7A anode voltage.

If you want to use a single-ended scale, put the scale reversing switch in the difference amplifier grid circuit. For positive voltages, one grid to ground and the other for signal; for negative voltages reverse grid connections only. You will probably find that you do not need to switch in a new calibration control for the reversed ranges. By swapping grid connections, the tube sees nearly the same operating conditions with opposite polarity signal input, so calibration should not be disturbed.

A lower-range meter may be used simply by changing the value of the calibration pot. A larger resistance reduces the current that flows through the meter for a given input voltage.

Construction

The VTVM is assembled on a 5 x 7 x 2 in. aluminum chassis, with a 4 x 7 in. panel tilted back $\frac{5}{8}$ in. at the top. A lip $1\frac{1}{4}$ in. wide takes a 1 in. wide vertical brace at each side for reinforcement. The lip is folded down $\frac{1}{4}$ in. at the back for reinforcement, also giving a convenient handle for picking up the instrument. The four little diagonal pieces visible in Fig. 3 are braces. They strengthen the chassis.

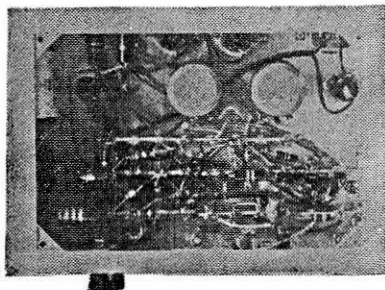


Fig. 3. Bottom view of dc VTVM. Voltage doubler supply is in lower right hand corner on two lug strips on side of chassis. Circuit warmup time might be reduced by mounting the transistor on top of the chassis.

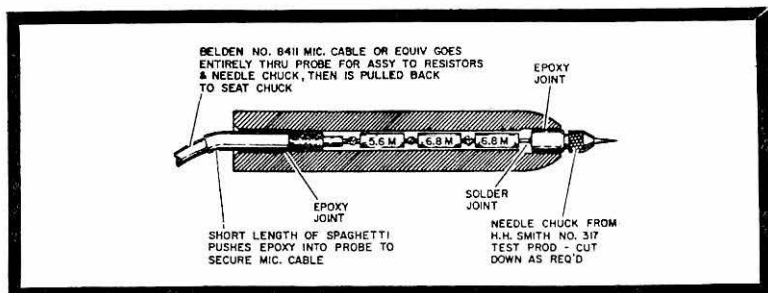


Fig. 4. Test prod construction. Simple design is permanently assembled with epoxy cement.

Parts positioning is not critical, but the signal input leads should be kept well clear of the heater and input wiring. The ac won't affect the instrument but you don't want it going back into the circuit you're observing. The voltage divider uses two 1-pole, 11-position wafers, the front one serving only for tie points. They are mounted on the appropriate manufacturer's shaft assembly, which may be supplied separately.

I mounted the transistor socket by its leads on two solder lugs. The wiring follows no special layout but parts close together on the schematic appear near each other in the chassis. The statistics on the five large solder lug strips are 28 insulated lugs and 5 grounded lugs used. B— and signal ground go to the metal chassis. The TV cheater cord power input is very convenient and only costs a few cents.

Since the Selectronics meter comes with no mounting brackets, the simplest way to install it is to glue it in. An Adel nibbler cuts a nice square hole, slightly oversize, and you might clean it up with a file. After painting, scrape off a couple of patches under the meter, roughen the plastic that goes over them, spread a thin layer of good epoxy, and slip the meter case in place. Leave the cover off. Let the panel rest overnight face up to complete the job.

I made the probe from a handy piece of phenolic plastic, a half-inch in diameter by 6 in. long. (Details in Fig. 4 and 5.) The rings around the lower end serve to indicate where the end is without looking at the probe. It's all held together with epoxy resin. Each half-watt resistor is rated at 300V, so it's quite safe for poking around in circuits within the normal range of the instrument. The needle chuck is cut down to reduce probe capacitance. I have a strong preference for the phono needle tips, since they can be wedged into something while making a

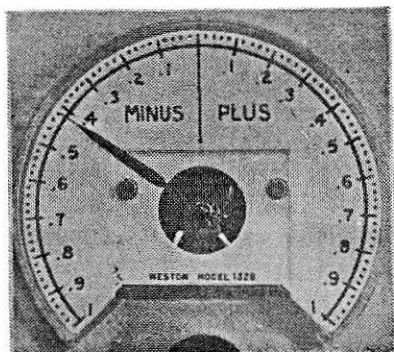


Fig. 7. Closeup of new meter scale, cover removed. Needle is at resting position with power off.

Meter calibration

The meter scale is large enough to draw by hand in real size. Instead of going into detail, I'll pass on some suggestions. You can browse around in a couple of drafting books for the necessary background. You will need a basic set of drafting instruments, which are usually available somewhere. Try a nearby school. If you're not a student, you may be a taxpayer helping to support the school.

Figure 7 shows a scale done with a Leroy penholder. A soft drafting pencil, properly used, will do a very acceptable job. You may feel more comfortable working in pencil if you lack previous drafting experience. Work on a piece of ordinary white filing-card stock. When the scale is prepared, spread epoxy cement thinly over the entire back, place the new scale over the old one and let the epoxy harden. If you don't like the end result, acetone attacks the epoxy. You can clean up and start over.

Begin by copying Fig. 8 onto the white stock. Ink or heavy in the scale arc, the center zero line (if used) and perhaps part of the lettering. Cut out careful, straight lines with straightedge and razor blade, the outside curve with scissors. Save the waste. You can fit it back into the scale to find the center for finishing up.

Masking tape will hold the scale in place well enough for calibration. Tiny pencil marks will indicate the new scale location over the original scale, since you must remove it for completion after calibration. Locate the endpoints by applying full-scale voltage in opposite directions. Find the nine intermediate points by draftsman's construction, or using a

voltage calibrator (because the meter movement isn't perfectly linear). Set the VTVM to 10V full scale and make a tiny pencil mark at each volt deflection. Return the scale to the drawing board for finishing, and then install it permanently.

The meter as received has its zero at the conventional left-hand end of the scale. I rezeroed it upscale by turning the hairspring attachments in the appropriate direction. About 90 degrees was the maximum available correction, the same change being made in front and back hairsprings. This brings the needle to the position shown in Fig. 7, and the zeroing to the new scale is completed electrically. This gives a possibly unnecessary option for future adjustments in either direction.

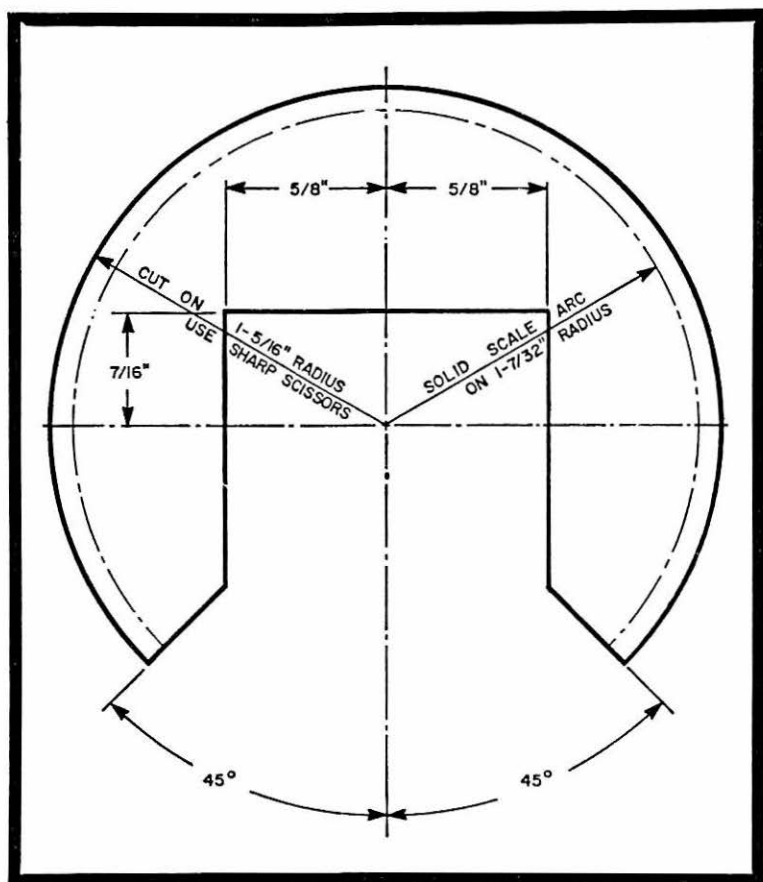


Fig. 8. Drawing for getting started on a new meter scale. Paper stock will not change calibration with humidity if properly glued to metal backing.

Finishing

All amplifiers show slow drifts which are lost in the capacitive interstage couplings of the familiar audio and rf amplifiers. But dc amplifiers see the drift as signal. This drift problem is usually dealt with by using very stable supply voltages and incorporating additional elements whose drift is about equal and opposite to that anticipated in the signal part of the circuit.

If your meter shows erratic zero behavior five minutes after a cold start, or annoying drift later than 20-30 minutes, look for a faulty circuit component. The best way to find the trouble is to choose one small region or candidate at a time, and invent a way to test it without disturbing everything else.

A surplus zeroing pot may have aged more than anticipated since last used, and be making poor contact. Let it hang by its leads so the shock is not transmitted to the chassis, and give it a rap with a small screwdriver handle. If the meter needle jumps, the pot at least needs some contact cleaner. Check other pots the same way, and poking at joints with an insulated rod will uncover poor solder work.

Having eliminated all possibilities in the chassis, rap the tube. As the tube warms up, mechanical stresses develop inside. One or two raps will relieve these. If the meter needle starts jumping one way and another on successive raps, you want a different tube.

Use a Variac to adjust the line voltage in little jumps. If the meter needle follows these jumps quickly, check the OA2s, the zener diode, and the bias transistor in that order. Slow drifts are acceptable.

The direct input x10 ranges turned out to have an immediate use I could have anticipated but somehow didn't. They're great for checking and neutralizing tiny VHF amplifiers.

A Sensitive RF Voltmeter

by Jim Fisk

One of the technicians's handiest test instruments is the rf probe or rf voltmeter. This unit may be used for neutralizing transmitters, tuning up oscillators, and in many other general tasks around the shop. Most individuals simply purchase an rf probe to go along with their VTVM; but these probes are usually limited to an upper frequency range of somewhere around 250 MHz. Another serious limitation of the familiar VTVM rf probe is that the lowest range on the VTVM is typically 1.5V full scale. Some of the latest models have voltage ranges down to 0.5V full scale, but the vast majority are not that sensitive. When working with transistor rf stages, millivolts (thousandths of a volt) become very important, and a more sensitive rf voltmeter than the common household VTVM must be used.

There are several approaches to this problem, but most of them are not very simple. The commercial instruments that read 1mV full scale or less are quite complicated; they rectify the rf, chop it up at 1000 Hz, feed it into a very high-gain, narrow-passband ac amplifier, rectify it at the higher level, and drive a meter movement. This is a very effective approach, but instruments using it cost upwards of \$500. The rf voltmeter described here is not nearly sensitive enough to read 1 mV full scale, but with care in construction, you can readily detect 30 or 40 mV signals at 500 MHz. This is about 15 times more sensitive than the most sensitive VTVM and about 50 times more sensitive than the average one. Higher sensitivities are obtainable, but noise becomes the limiting factor with the construction described here.

With this rf probe, response is relatively flat from about 50 all the way up to 500 MHz. The secret to this unit's wide frequency range lies almost exclusively with its layout and construction. First of all, the probe itself is essentially coaxial

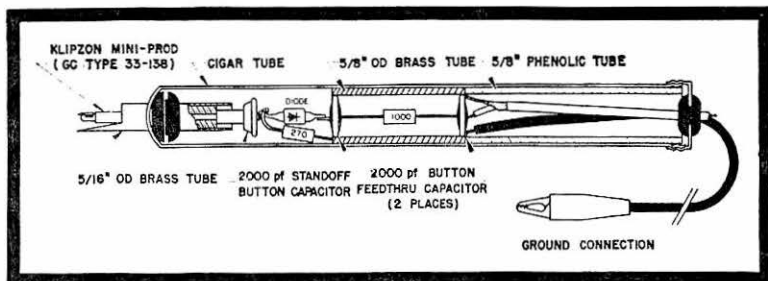
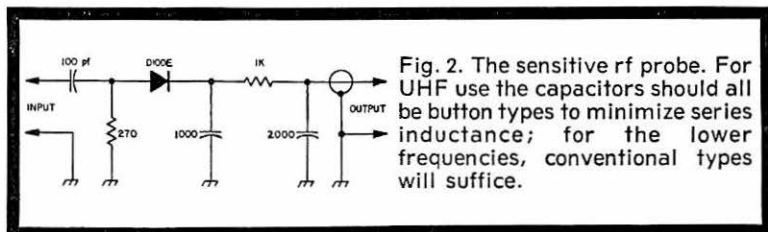


Fig. 1. Cutaway view of the sensitive rf probe. Note that the cigar tube construction results in an essentially coaxial structure; this type of construction insures relatively flat response up to 500 MHz.

in nature, with the filter components mounted in a brass tube. To maintain leakage at an absolute minimum and to minimize series inductance, button mica capacitors are used in conjunction with a coaxial input. The result is a probe that will accurately measure small levels of rf voltage up to about 500 MHz. Above 500 MHz, you can still get meter deflections with small rf voltages, but the response gradually falls off. This frequency rolloff is a result of the parasitic and leakage elements that start to take effect at higher frequencies. Above 500 MHz, for example, it is difficult to predict the dielectric characteristics of molded carbon resistors. In some cases there is sufficient leakage between the two leads of the resistor to completely nullify the resistance.

In addition to the compact and coaxial nature of this probe, the low value of load resistance, 270 ohms, tends to maintain an input-output characteristic that is almost completely independent of frequency up to 500 MHz. With the component values shown in the schematic, the response gradually falls off below 50 MHz; at the expense of flat UHF response, the capacitors may be increased for response in the 3 to 30 MHz region. For the high-frequency range, the input



coupling capacitor should have a value of about 500 pF and the filter capacitors should be 2000 pF. For lower frequency use, of course, it is not necessary to maintain the coaxial structure of the probe nor to use the more costly button capacitors.

The selection of a diode depends on the frequency range desired. Up to about 100 MHz, almost any germanium diode will work quite well; the 1N34A is an excellent choice for this range. For higher frequencies, however, many diodes are constructed in such a way that they exhibit high values of series inductance and leakage capacitance. For this reason, the familiar 1N21 and 1N23 microwave mixer diodes represent excellent choices for a voltmeter of this type designed for VHF use. The 1N82A is another diode that works quite well up to 1000 MHz or so. Each of these diodes exhibits different characteristics and even diodes of the same type are not exactly identical.

It is a pretty well known fact that semiconductor diodes exhibit a square-law input-output characteristic up to several hundred millivolts. With germanium diodes, the square-law region is from zero to about 100 or 200 mV; silicon diodes are slightly higher, to 600 or 700 mV. The 1N34A diode, for example, exhibits a sensitivity of 700 to 1200 $\mu\text{A}/\text{V}^2$ in this region; a typical 1N34A $\mu\text{A}/\text{V}^2$ curve is plotted in Fig. 3. It should be pointed out that this curve varies with temperature, the amount again depending upon the individual diode used. In typical applications this is usually not a problem, because the probe will normally be used at room temperature. Above the square-law region, the sensitivity of semiconductor diodes is essentially linear and typically on the order of 5 mA/ V^2 .

Because of the large variance between diodes, the rf probe must be calibrated against a known source for maximum accuracy. Because of the construction of this probe, the calibration sounds much more complicated than it actually is. Since the probe is essentially flat up to 500 MHz, it may be calibrated at 100 MHz or so; most VTVMs are accurate enough at this frequency for calibration purposes. All you have to do is set the output of your signal generator for 1V on the VTVM. For best results, your generator should be operating on a fundamental and relatively free of harmonics. Since 1V is within the linear range of the diode in the VTVM rf probe, it should be reasonably accurate. Now all you have to do is connect an attenuator. You can breadboard an attenuator circuit for this purpose or use a switchable attenuator. When

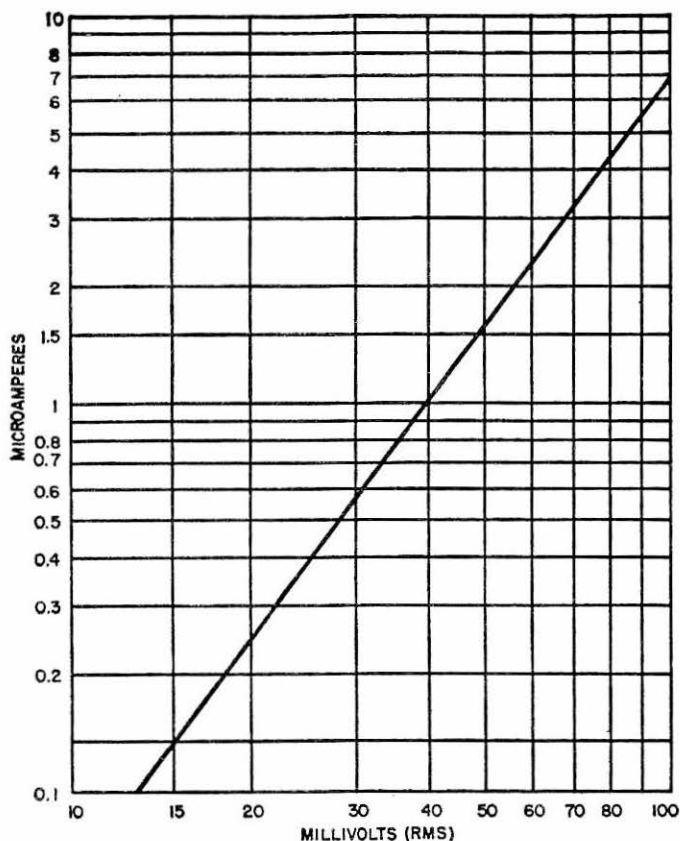
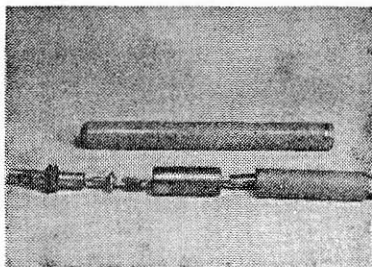


Fig. 3. The microampere per volt characteristic of a 1N34A diode in the square-law region. Above 100 millivolts or so, this curve becomes linear.

the input-output characteristics are plotted on graph paper, you would end up with something like the curve of Fig. 3.

Construction of the probe is quite simple and is based upon the use of an aluminum cigar tube. If you can't get one of these or don't smoke, an old penlight or piece of aluminum tubing will work with a little modification. The tip of the probe is made up from a Klipzon mini-prod (General Cement 33-138) and a piece of 5/16 in. brass tubing from the hobby shop. This tubing is popular with slot-car enthusiasts, so it shouldn't pose any procurement problems. One end of the mini-prod has a

Disassembled rf probe. The Klipzon Mini-prod is on the left, the button coupling capacitor, diode and 270 ohm resistor to the right, followed by the filter and phenolic tube. The cigar tube housing is in the background.



sharp tip with a small clip that may be clipped onto wires; the other end accepts a pin plug.

Apply a little epoxy to the mini-prod and push it into the brass tubing. The mini-prod fits snugly in the tuning and is held firmly in place by the cement. Now place a 5/16 in. rubber grommet around the tube and push it about halfway down; cement it in place with epoxy.

While the epoxy is setting, take a 100 pF standoff button mica capacitor and solder it to a pin jack; this will eventually fit into the end of the mini-prod when the probe is complete. Cut a piece of 5/8 in. brass tubing about an inch and a half long and solder two button capacitors and a 1000-ohm resistor inside as shown in Fig. 1. This "filter" assembly should slide easily into the cigar tube. Also drill a 5/16 in. hole in the end of the cigar tube for the mini-prod assembly.

Install the diode and a 270-ohm resistor as shown in Fig. 1, using the shortest leads possible. The cathode of the diode goes to the center pin on C2; the 270-ohm resistor is soldered to the brass tube. On the other end of the tube, connect a length of cable; this lead will be connected to the microammeter. Install the complete assembly (mini-prod, C1, CR1, R1, and the filter) into the cigar tube and cut a length of 5/8 in. phenolic tubing so that it protrudes about 1/8 in. from the end of the cigar tube. When the cover is in place, this tube will compress the unit together and insure a physically strong assembly. The shielded lead is brought out through a small rubber grommet mounted in the cover.

In addition to the rf probe, you will need a very sensitive microammeter for measuring small levels of rf. Occasionally 10 or 20 uA movements are available at bargain-basement prices, but usually another approach is necessary; the sensitive microammeter illustrated in Fig. 4 is a good example. This meter uses a high-gain transistor meter amplifier to

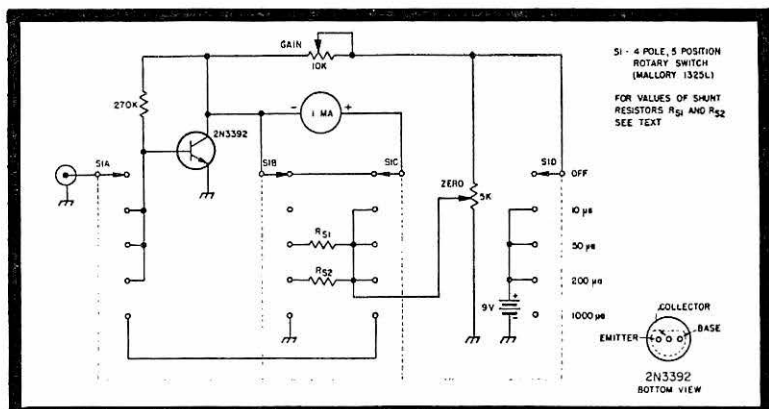


Fig. 4. Transistorized microammeter. This instrument will provide full scale readings down to 10 μ A. Although a 2N3392 was used here, any high gain silicon transistor that maintains high current gain at low collector current levels is suitable.

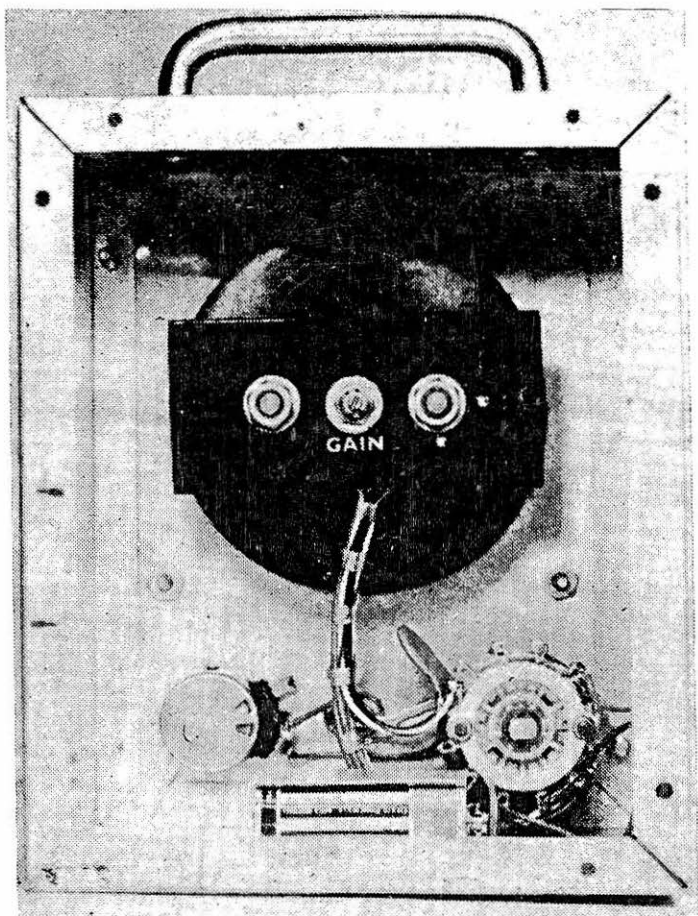
obtain full-scale readings down to 10 μ A on a 1 mA meter. With a full-scale calibration of 10 μ A, it is quite easy to read a half microamp or so; this corresponds to 28 mV peak to peak with my probe.

The sensitive microammeter illustrated schematically in Fig. 4 consists of a current amplifier with the 1 mA meter in a bridge circuit. This circuit is quite stable with temperature and slight variations in supply voltage may be compensated by the zero control on the front panel. Almost any high-gain transistor will work in this circuit, but silicon is preferred because of its better leakage characteristics. The only other requirement is that the transistor maintain linear current gain and high beta at low collector current levels; the 2N3392 is inexpensive and works very well.

With the switch in the 10 μ A position, the 10K gain control is adjusted to provide the 10 μ A full scale. With a 1 mA movement, this corresponds to a current gain of 100.

In my transistorized microammeter I mounted the transistor amplifier circuitry and meter shunts on a phenolic strip connected to the meter terminals. The gain potentiometer is also mounted on this strip. With a circuit as sensitive as this, noise can be a very serious problem if the circuit is not properly shielded. In this case a small coaxial cable was used in the input and the amplifier and meter were built into a metal box. In addition, the input was bypassed with a 0.01 μ F disc capacitor.

With the sensitive microammeter and calibrated probe, it is quite easy to accurately measure rf voltage down to 30 or 40 mV. However, since this is a peak responding instrument, you have to be a little careful or you will obtain some very optimistic readings. If there is any harmonic content in the waveform you are reading, it is apt to be quite a bit higher than predicted, and the rms value will not be 0.707 of the peak reading; the 0.707 value applies only when the waveform is sinusoidal. This is not usually the case with rf oscillators and amplifiers, but if the harmonics are suppressed with high-Q tuned circuits, the error will be negligible.



Inside of the meter amplifier. The transistor and gain calibration control are mounted on a piece of Bakelite attached to the meter terminals.

In addition to measuring actual rf voltages, this probe has several other uses. It may be used as a sensitive untuned field-strength meter by simply clipping a short length of wire to the tip; in some cases where the rf field is strong and the probe can be placed close enough to the transmitter, this may not be necessary. Hence another precaution: don't use the probe in strong rf fields when measuring small rf voltages; the rf field will negate the voltage reading.

This probe may also be used as a demodulator for a VHF sweep generator. Just connect the probe to the circuit being swept and connect the output to your oscilloscope. It may also be used to measure the swr along a piece of open-wire transmission line (or twinlead). When the probe is brought in close proximity to the transmission line, it will provide an upscale reading on the microammeter. The ratio between peaks and valleys as the probe is moved along the line is the voltage standing wave ratio.

In some measurements you may find that the probe will load low-capacitance high-Q circuits. If you are only interested in peaking the circuit, this effect may be minimized by connecting a resistor in series with the probe. The Klipzon mini-prod is ideal for this purpose because it will securely hold one lead of the resistor; the other lead may be used for probing. If a 5000-ohm resistor is used, it represents less than 1 pF coupling above 30 MHz; this should eliminate any detuning effect of the probe.

There are many other uses for the sensitive rf probe, limited primarily by the ingenuity of the user. But in its main application, that of measuring very small rf voltages, it is unbeatable for its expense and complexity. Although high rf voltages or mechanical shock may cause permanent damage to the diode, my probe has proved to be particularly resistant to burnout and has accepted peak surges of 500V dc and 120V ac with no apparent effect on calibration.

Measuring Relative RF Power

by Bill Hoisington

This article describes a very useful gadget for determining the rf power output of solid-state VHF/UHF transmitters in the difficult range to measure, from about 10 mW up to 5 watts. It does not read watts directly; but by a simple comparison of calibrated pilot light brilliance, it will tell you how many watts you are putting out, to within a couple of decibels. It allows you to check power increases and estimate your efficiency quite close.

Principle Involved

We'll start right in with this part because, while this unit is not by any means a "trick," it does not read rf directly. You first light a pilot light as a good dummy load, matching it into the rf tank circuit of your transmitter by the normal means, also noted here.

You then switch on a second bulb of the same type by means of a battery, controlling the light output with a \$1.30 wirewound potentiometer in series, as shown in Fig. 1. This pot must be previously calibrated in milliwatts, as by the method of "volts times milliamperes equals milliwatts." You then match the brilliance of the bulb lit up with rf or its dull glow at some 18 to 25 mW if you're just getting your transmitter going, and read the watts on the wattmeter dial. It's astonishing how well it works, how repeatable it is, and how you wouldn't be without it once you build and calibrate it.

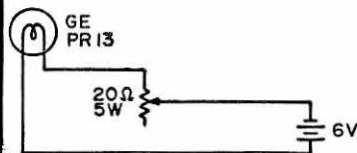


Fig. 1. The circuit supplies the brilliance "standard" for comparison. When the "standard" lamp is mounted adjacent to the dummy load, the pot permits variation of the standard to match the load. If the resistance is panel-marked in watts, a good power indication is achieved.

Using Milliammeters for RF Watts

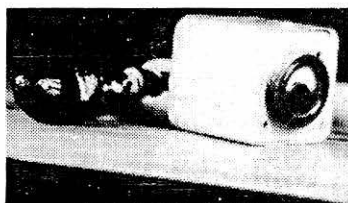
by Marc Leavey

The meter described here is as accurate as components allow, and it's easy to build. The calibration is logarithmic, which means that a simple graph is possible, and easier than changing the meter scale.

For the mathematicians, I will present the formulas upon which this device is based, and ways of modifying it; for those of you who avoid math whenever you can, look at the graphs and skip these few paragraphs.

To spare undue complexity, assume 51-ohm line—other values can be dealt with later. Perhaps the easiest parameter to measure, and one that is proportional to power, is rf voltage. A voltmeter can be made most easily with a series resistor and a 0-1 mA meter. Now let's plunge into the actual calculations.

Assume W is the full-scale meter reading in watts, Z is the line impedance, E is the voltage measured, I is the full-scale meter reading in amps of the basic meter, and R is the value of the series resistor in ohms. We know that the voltage (IR) is equal to the square root of "impedance times power," or 14.270V. Now, since the voltage and the current (0.001A because the full-scale movement is 1 mA) are known, simple division yields 14,270. The resistor value, then, is 14,270 ohms. The upper portion of Fig. 1 is a graph that will enable the nonmathematician to choose the value of the resistor for full-scale readings up to 4 kW, with 51-ohm line and 0-1 mA meter.



Front view of unit.

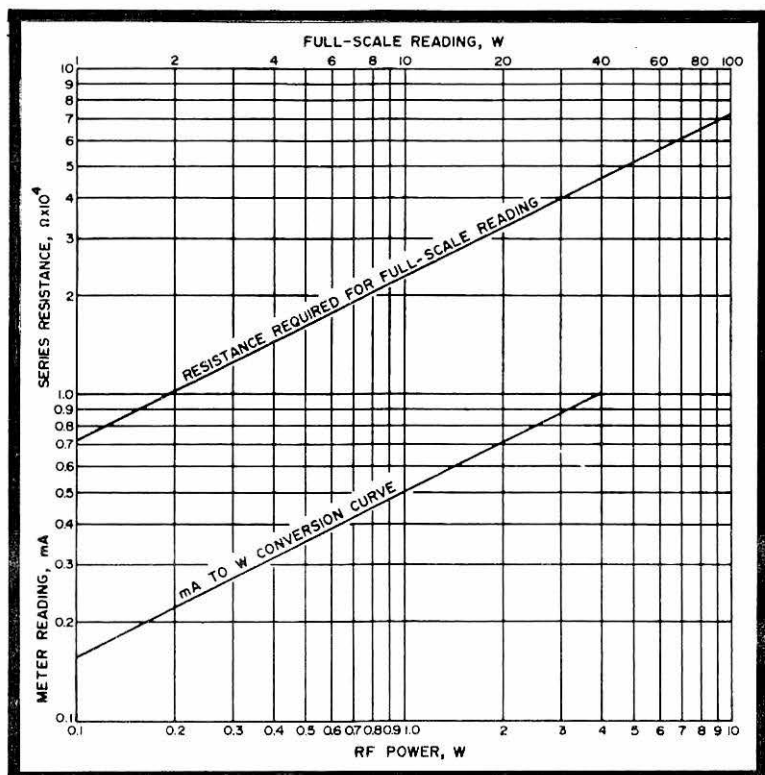
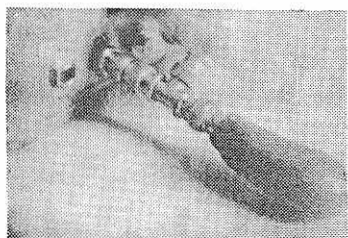
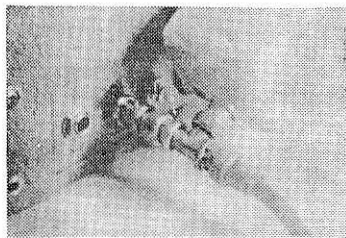


Fig. 1. Logarithmic plots for determining power. The upper curve gives resistance values for determining what the full-scale meter deflection will be (remember to multiply the series resistance value shown on the chart by 12K. The lower curve will allow you to determine your precise power out if you use a 0-1 mA meter.

Although this is the calibration of the prototype, for 4W full scale, it will multiply for 40, 400, or 4000W. A half-scale reading, 0.5 mA, corresponds to 1W (1 kW, etc.). This spreads out the range below 1 kW for ease of reading and measuring.



Connection to transmitter with dummy load (see text).



Connection to transmitter with antenna connected.

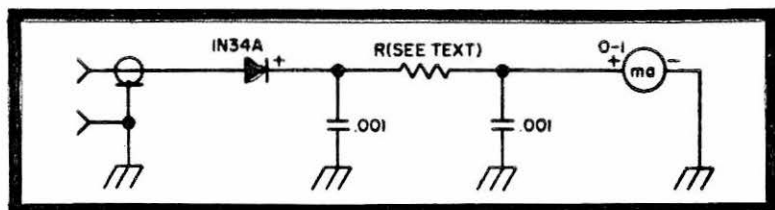


Fig. 2. Schematic diagram of the simple, accurate, and easy-to-build rf wattmeter.

Now get out that soldering copper and gas pliers, and build it. As the schematic (Fig. 2) shows, the circuit is a basic rectifying-type rf voltmeter. The prototype was built in a small can of the plug-in-module variety that was scrounged from the junkbox. About the only critical part is the series resistor. The capacitors in the prototype were mica, but ceramic discs would work as well. The diode can be a 1N34A, 1N270, 1N52, 1N38A, or just about anything else. Use the old technician's rule of thumb: "When in doubt, try it out!"

Two sockets might prove more convenient rather than one with a coaxial tee as shown. Conventional minibox construction or building into a new or existing rig will be more than adequate. Point-to-point wiring is used to permit compactness and reduce lead length.

"Fine," you say, "but I don't have a huge mound of test equipment. How do I calibrate it?" That is the beauty of it—you don't! If the series resistor is accurate, the meter will be self-calibrating to a log scale. Remember, you know R and Z , and the full-scale W . Now assume a half-scale reading $I=0.0005$, and calculate W for half-scale. Plot these two points at 1.0 and 0.5 mA on Fig. 1, and connect by a straight line, which you may extend the length of the graph.

Install the meter through a coaxial tee at your antenna connector, or through some other predetermined means, and terminate with a dummy load. The one seen in the picture is three 150-ohm resistors in parallel, dipped in epoxy, shielded with a copper braid, and installed on a BNC plug. Apply power and read the meter. That's it! The meter can be used with an antenna if your swr is below about 1.2:1.

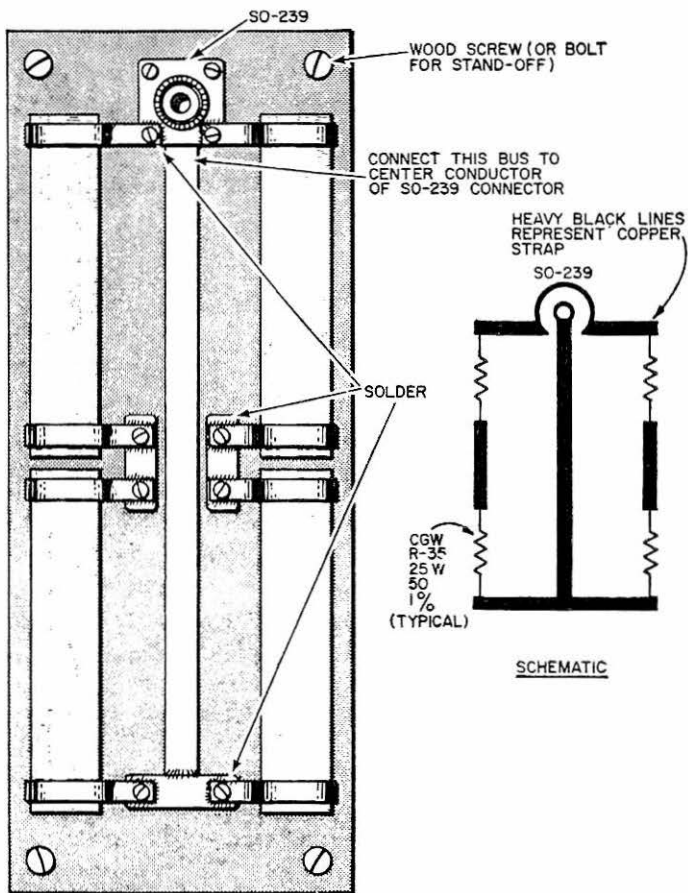
A 100-Watt Dummy Load

by Neil Johnson

"Noninductive, late style 50-ohm, 25W resistors, 35 cents" said the ad. So I bought four of these (Meshna Supplies, Box 62, East Lynn, Mass., 01904) four of these in series-parallel connection should give 50 ohms effective resistance, with 100W of heat-dissipating ability. Anyone can see from our most elementary drawing that you don't need to be an electronic genius to duplicate this very simple item. The only additional cost was for an Amphenol type SO-239 fitting and the surplus fiber-glass board on which the whole assembly is mounted.

If you feel really "sharp" you might choose to run the center conductor in the form of a three-wire bus, or maybe a copper strip. This is supposed to cut down on "stray inductance" and make the dummy load resistance closer to 100-percent nonreactive. I checked out the final product and found that the swr was fairly low on 40 meters, reading 1.05 to 1 on a Knight swr meter. This rose to 1.2 to 1 on the 21 MHz band. Maybe the resistors are noninductive at 2 or 3 MHz, but they seem to become more reactive as the frequency increases.

It might be possible, with a little experimenting and a different physical layout, to come up with a cancellation of most of these effects, and possibly bring the swr down to 1.1 to 1 throughout the HF amateur and citizens bands.



Details of the Meshna-special dummy load. The resistors are 35 cents apiece. The board is 4 x 10", and preferably fiber glass or Bakelite. The resistors are supported by 1/2" or longer spacers.

An Inexpensive RF Wattmeter

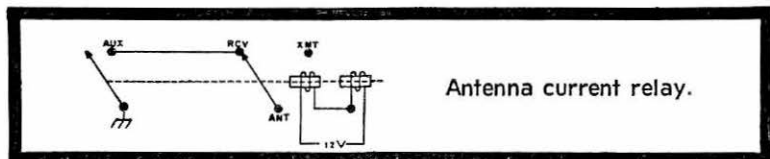
by Walt Pinner

While on vacation recently, I was rummaging through the various surplus outlets in the Detroit area. Among the goodies purchased was a small surplus "antenna current indicator." It has a 2½ in. meter movement, three spring-loaded feed-through connectors, and a power plug for connection to an internal antenna relay. It also includes the pickup unit and shunt necessary to operate the meter. The unit is a thermocouple-type antenna current indicator. Its nameplate states it was manufactured for the Army Signal Corps under the name of Antenna Current Relay Unit BC442-AM.

The unit has a fitted bottom cover and ample room to install two SO-239 connectors in place of the feedthrough connectors already there. The antenna changeover relay is mounted to a plate and secured to the box with four screws. It may be removed as an assembly for use elsewhere. The rf contacts appear to be more than adequate for amateur use up to the legal limit of power. The rf contacts have an additional single-pole contact which may be used for B+ control or grounding of the receive antenna lead during transmit, as shown in the diagram.

The relay is operated by two series-connected coils and requires +12V at 80 mA. If the coils are parallel-connected, a 6V source may be used. A single diode with a small filter on the rig's filament supply works nicely.

The meter scale reads from 1 to 10. Comparison readings of this unit, with no change other than substituting standard



coax fittings, were made against a Drake W-4 wattmeter into a 50-ohm dummy load. The results:

BC442 reading	Power (watts)
1	.100
2	.200
3	.300
4	.400
4.9	.500
5.5	.600
6.2	.700
6.9	.800

These readings remained constant over a range of frequencies from 3.5 to 30 MHz. Power levels of 25, 50, and 75 watts may be read with reasonable accuracy if the mechanical zero meter setting is adjusted with the meter in the vertical position and the power readings taken with the meter in the same position. The best part of this unit is its price. It was purchased from Bauer Industrial Supply, Redford Ave., Detroit, Michigan for \$3, less his 15-percent discount (to anyone) which lowers the already ridiculous price to \$2.55 plus tax. A terrific buy for your surplus buck.

Hot-Carrier-Diode Milliwattmeter

by Frank C. Jones

The present low price of about one dollar for hot carrier diodes (HP2811 or 2800) helped greatly in working out the two rf milliwattmeters shown in the circuits and photographs. They cover the range from audio up to 450 MHz.

A milliwattmeter is extremely useful in checking the output of any transistor or tube oscillator such as those used in transmitters, vfo units, receivers, and VHF converters—providing the oscillator has a 50-ohm output connection. A temporary 50-ohm output connection can be made to any oscillator, doubler, or tripler tuned circuit by one or more turns of wire around the coil and running the rf output to the milliwattmeter through a short lead of coaxial line. If a measurement at any frequency shows a milliwatt or two into a 50-ohm load, you can be reasonably sure of enough rf injection even into a high-impedance mixer. Some FET mixers require about 5 mW injection, so if the measurement into an rf milliwattmeter indicates this amount is available, most of the tedious work is done in designing or checking this part of a receiver or transmitter. A vfo control unit may need to have constant output over its whole range. Measurements of rf power over the whole range is needed in this case, which may

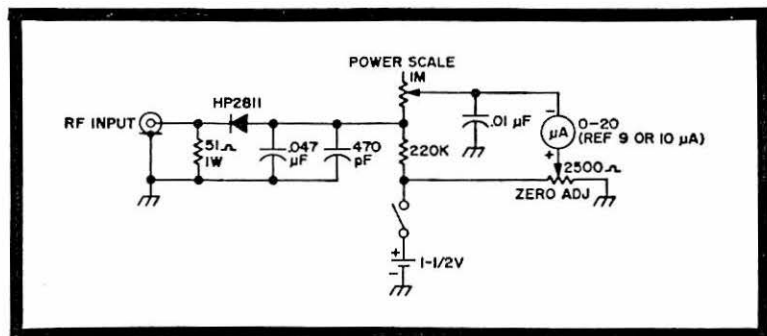
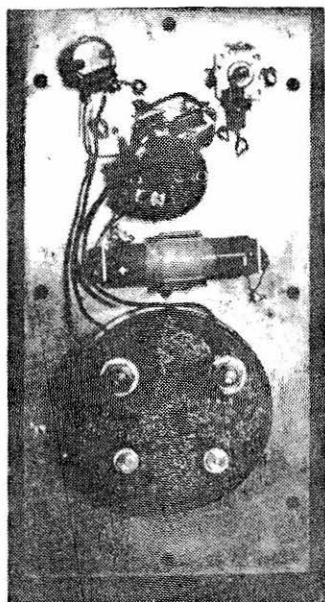
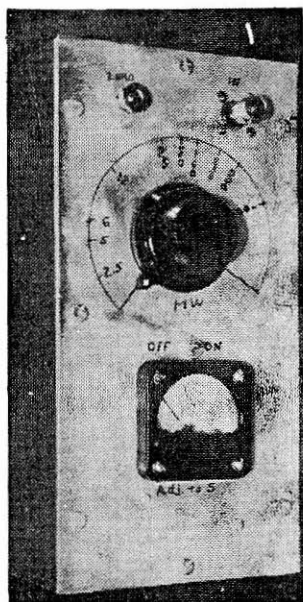


Fig. 1. Schematic diagram of 0.05-500 mW wattmeter.



1 to 1000 milliwattmeter top view,
4 x 8 x 2 inch case.



1 to 1000 milliwattmeter bottom
view.

only take a minute or two. The time to iron out vfo irregularities is something else!

The parts needed in a simple rf milliwattmeter are relatively few in number and moderate in cost. The microammeter is used only as a reference indicator so no scale calibration is required. A black line on the meter face cover at the desired 5 or 10 or 15 μA is all that is needed. The rf power calibration is made on the dial or scale of the high-resistance variable resistor or potentiometer such as used for af gain controls.

The HP2811 (or 2800) hot carrier diode is remarkably uniform in characteristics from unit to unit. It is also usable with a forward bias dc voltage which greatly increases its sensitivity as a detector. All diodes have a minimum voltage below which the rf current flow is too low to be useful in a microammeter which is a current indicating device. If an ordinary diode has forward bias, it may become a good noise generator or erratic in operation.

The diodes used in these rf meters work very efficiently with some forward bias from a small 1.5V battery. The current

through the diode is limited by a series resistor or some value between 180K and 200K. The dc path is completed through the diode and the rf terminating resistor of 50 or 51 ohms. This bias voltage also causes a current to flow through the microammeter, which preferably should be balanced out for low rf power measurements. This current is greatest when the power indicator variable resistor is set to minimum resistance.

By balancing out this current by means of a screwdriver-adjustable potentiometer so the meter reads zero with no rf power input, one reference line on the meter face can be used for any rf power input at any frequency. The dc drain on the battery cell is a value of less than 1 mA when making measurements, but the life of the battery can be extended greatly by having a switch in this circuit.

The 51-ohm 1W resistor (Fig. 1) should be a noninductive, carbon- or metallic-film type suitable for rf service. Actually a $\frac{1}{2}$ W type has a little better rf characteristic but no resistor should be used at full rating. This terminating resistor is soldered across the BNC rf input fitting with as short leads as possible. The diode and its parallel bypass capacitors are also mounted at this input jack. All other components can be mounted anywhere on the 4 x 8 x 2 in. chassis panel (or other sized case if desired).

In the other higher-range rf meter (Fig. 2), the rf resistor consisted of two resistors in series with short leads across the BNC input jack. A 39-ohm 1W and an 11-ohm $\frac{1}{2}$ W resistor in series make up the 50-ohm rf load. The diode is tapped into this resistor in order to keep within the 15 or 20 PIV rating of the HP2900 or 2811 diode. (An HP2800 with its 75 PIV rating could be used across a 50-ohm resistor.)

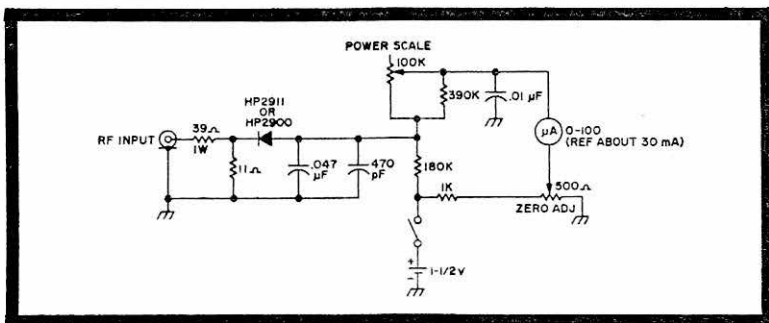


Fig. 2. Schematic of milliwattmeter for measuring rf power levels of 1 to 1000 mW.

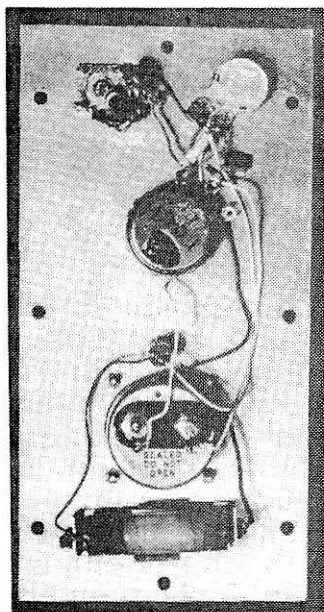
Parallel bypass capacitors were used from diode to ground of the input jack in order to use the instrument over the whole range of 50 kHz to 450 MHz. With even larger bypass values in parallel, the milliwattmeters could be used throughout the audio range as well; and calibration of the power scale resistor could be made more easily. A sensitive af or low rf voltmeter and an oscillator within the voltmeter frequency range can be used to calibrate the devices. The oscillator needs to have an attenuator, a low impedance output, and a power output of up to 1W for connection to the milliwattmeters through a piece of 50-ohm coaxial line. Calibration measurements can be made using the low-power stages of a 450 and 150 MHz transmitter limited to about 500 mW. A series of 3, 6, 10, and 20 dB resistor pads (1W maximum ratings) with 50-ohm impedance values are then cut into the coax line to check calibration points at 150 and at 450 MHz. The maximum errors should be less than 15 percent—and at most frequencies, much less.

The component values shown in Fig. 1 resulted in an instrument having a range of 0.05 up to 500 mW. The low end of the power range will depend on meter resistance to some extent.

The unit shown in Fig. 2 used a small square microammeter without microampere calibration but the full-scale deflection point seemed to be a little over 100 μ A. The reference line of rf power indication was simply a black ink line on the face of the meter. The popular imported 50 μ A meters may be used in this same circuit, though the higher meter resistance may prevent getting down to less than 0.25 mW readings in the circuit of Fig. 1. The minimum reading of 1 mW up to 1W or the unit in Fig. 2 may be easily obtained with nearly any range of microammeter and "power indicating" resistor. This variable resistor or potentiometer can be nearly any size of af gain control with its maximum resistance either limited by a shunt resistor or by the pot value itself, depending on the range or reference value of the microammeter.

This resistor scale was hand calibrated on an aluminum panel in the higher-range instrument and on a brown Bakelite copper-plated board in the low-range unit.

The zero adjustment circuit of Fig. 2 with a 500-ohm pot and a fixed 1000- or 1200-ohm resistor makes it an easy matter to zero the meter. Less than 500 mV of bias is needed for the meter circuit. A few microamperes of forward bias current



.05 to 500 milliwattmeter, underside view of completed 4 x 8 board mounting.

through the diode is enough to enable measurements down to a small fraction of 1 mW.

About 30 different germanium and silicon diodes were tried in these circuits. Even the "fastest" computer diodes were not very good at 450 MHz. These function, but at lower efficiency than at HF or VHF—so the power scale error becomes objectionable. The hot carrier diodes were much better.

Hot-Carrier-Diode Wattmeter

by Frank C. Jones

Two rf wattmeters are shown here, one with a range of 25 mW to 10W and the other covering the range of 5 to 300W. Both are useful from low radio frequencies on up through 450 MHz.

The low-power version (Fig. 1) makes use of a 20W Sierra dummy antenna built into the meter case, though the metering circuit only goes up to 10W. If the maximum is to be 20W, the reference meter reading could be about 45 μ A instead of 30. The minimum power reading would be doubled. In this wattmeter, the power range potentiometer is calibrated and only a reference line on the meter is used when making rf measurements. The 50-ohm dummy antenna resistor is rated up to 1000 MHz, so is excellent from 450 MHz down.

The range potentiometer had an audio (nonlinear) taper. By connecting the "high" resistance end to the diode, the watt range scale is spread out quite well in the range of 100 mW to 10W. The hot carrier diode, an HP 2900, has a 10 PIV rating, which means that the rms rf voltage across it should be less than 3V for safe operation. At 10W of rf power, the rms voltage would be a little over 22V, which means a voltage divider is needed to keep the applied diode voltage down to about 2V. An HP 2800 diode with a 75 PIV rating would be more desirable, especially if the meter was to be calibrated for 20W maximum. This diode is about \$1 and has a little higher capacitance, which would require a different shunt capacitance across parts of the resistor divider to make the device work with the same power range calibration.

The divider should use half-watt resistors of the carbon or metal film type, since these units are part of the rf circuit. It is better to use three half-watt 300-ohm resistors in the string rather than a single 900-ohm 2W resistor; this is because the rf resistance characteristic is usually better in quarter- or half-watt types in certain ranges of resistance. Every resistor has some inductance and shunt capacitance which becomes part

of the voltage divider. The diode shunt capacitance is in parallel with that of the 110-ohm quarter-watt resistor in Fig. 1. However, nearly any combination of resistor sizes can be equalized within 10 to 20 percent over the desired frequency range. This divider is across the 50-ohm dummy antenna, so should not shunt the value down to less than 49 or 48 ohms. This divider has to dissipate a little rf power also. Its total resistance should be at least 20 times as high as the dummy antenna load resistor.

The values shown in Fig. 1 are just about the minimum that should be used. Too-high values make it more difficult to extend the frequency range to the upper end, though it can be done, as was discovered in the higher-powered wattmeter of Fig. 2.

All diodes are poor rectifiers at applied rf voltages below their forward bias values of 300-700 mV (peak). By using a forward dc bias voltage to make the diode conduct at a minimum of 5 or 10 mA, the detection sensitivity is increased as much as 5 or 10 times. This requires a small battery, a couple of fixed-value resistors, and a potentiometer to balance this current out of the meter when measuring rf powers below 100 mV. If the power range is limited to a minimum of 250 or 500 mW, no bias circuit is needed in this 10W instrument. The range scale in either case has to be hand-calibrated.

A low-powered radio transmitter or exciter can be used as a 10W power source when calibrating the power range pot scale. The transmitter can use stage detuning to reduce power outputs down to the lower values needed. Many swr meters have "watts of power" calibration, and one of these can be put in the coax line to the rf wattmeter for calibration service. A more accurate calibration can be made by comparing the power readings against some reliable commercial rf watt-

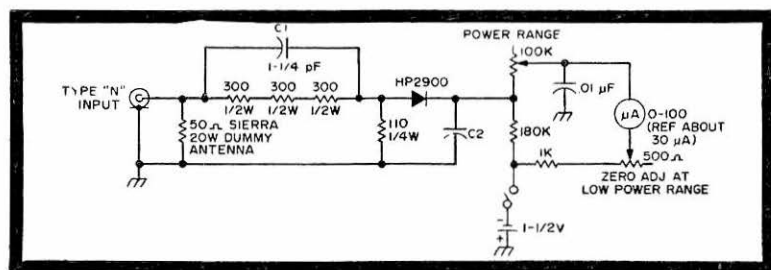
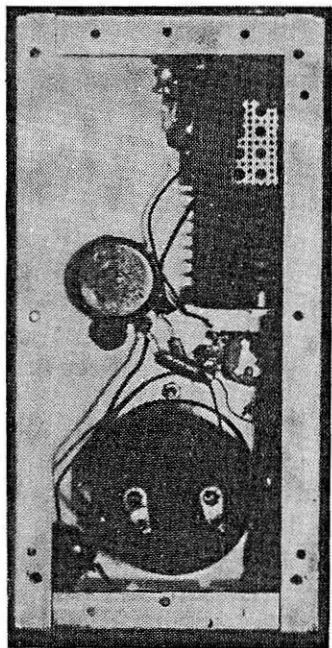


Fig. 1. Rf wattmeter for 25 mW to 10W.



Bottom view of 10W unit with the rf dummy antenna clamped in one corner.



Top view of low powered rf wattmeter covering .025 to 10W. Built into a 8x4x2 chassis with wire screen bottom plate for ventilation.

meter within its frequency range and calibration charts. This scheme is usually necessary for checking the calibration at VHF or UHF. Another method is to use an accurate rf voltmeter across the dummy antenna connection to ground and read the power values in watts $= E^2/R$. For example, 5V (rms) squared is 25; and divided by 50 ohms is equal to 500 mW.

The Sierra 50-ohm dummy antenna has no connection available at the high end of the resistor, which terminates in a type N fitting. The metering circuit has to connect to this point as close as possible by getting into the inner conductor of a coax fitting, or by drilling a small hole ($\frac{1}{2}$ in. or so) through the shell of the dummy antenna close to the rf fitting end. This can be done and the first 300-ohm resistor in the voltage divider soldered to the inner connection of the large 50-ohm resistor. A long $\frac{1}{8}$ in. diameter soldering iron tip is needed. The divider resistors, diode, and four 0.001 uF stud-mounted bypass capacitors were all mounted around this large hole in tapped 6-32 holes for the four capacitors.

Larger values of bypass capacitors can be shunted across these 0.001 μF values to ground to extend the frequency range down to low rf or even af values. For example, a 0.02 μF capacitor shunt would allow operation to 2 MHz. A miniature 50 or 100 μF electrolytic shunt would function at audio frequencies down to 300 Hz.

The diode must have a low-impedance path to ground over the desired frequency range to function as a peak rectifier and get as much dc output voltage as possible for the meter circuit. The microammeter in series with a variable range resistor is simply a dc voltmeter. The diode rectifier converts rf voltage to dc, so the diode should be equally efficient over the whole rf range.

The 5-300W unit was built to use with a large dummy antenna rated up to 500 MHz, which is a massive unit external to the box shown in the photographs. Quite a bit of rebuilding went into this device to make one calibration of the range potentiometer fit all frequencies from 450 to 2 MHz. The input and output coax fittings had to be finally mounted so the inner conductor tips could be soldered together and the resistor divider connected to this point. The latter consisted of two 4300-ohm 2W carbon resistors and a 68-ohm 1W resistor in series to a copper sheet inside of the aluminum box.

The watt range variable resistor was a 500K linear potentiometer which was limited to a lower value by shunting it from the moving arm to the diode connection end with a 220K resistor. This gave a maximum power reading of 300W when the reference line was drawn on the meter face at 12 μA . The import, low priced, 30 μA meter had a large meter scale. A smaller 0-50 μA meter would have been usable, since the meter is used only as a reference. The range pot knob is adjusted when rf power is applied to run the meter reading up to the line drawn on the meter scale face.

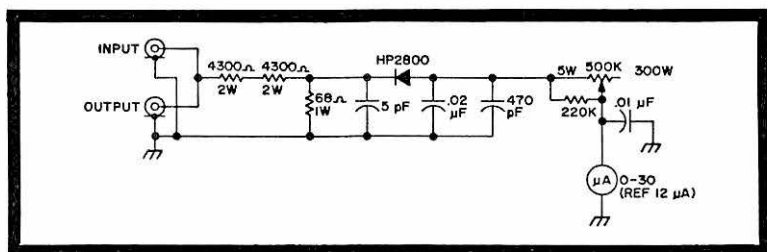


Fig. 2. 5 to 300W RF wattmeter metering circuit. External 300 or 400W during antenna load.

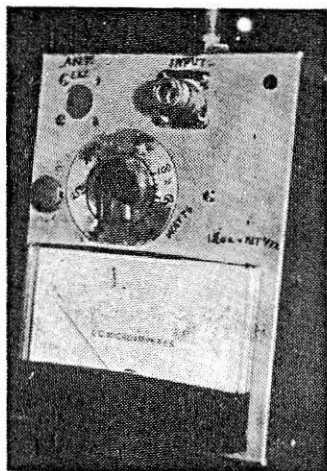


Fig. 3. Top view of 5 to 300 metering circuit for use with external high powered dummy antenna.

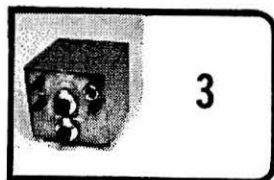
The circuit shown in Fig. 2 was equalized to within about 15-percent error over the range of 2 to 450 MHz by shunting a 5 pF capacitor across the 68-ohm resistor in the rf divider.

Calibration of this device was made at 150 MHz using a transmitter having up to 400W available carrier output. The meterizing unit was connected to a large Bird rf wattmeter at the external fittings of the latter. Several thermocouples had to be used to cover the wide range of power for the calibration. This required reading a chart curve for each Bird wattmeter reading and using correction factors for frequency in order to obtain the actual watts of rf power. Now, the large unit is used without the thermocouples, charts, rf choke, etc. simply as a dummy antenna. The new metering circuit connects directly into the antenna fitting, with a few feet of 50-ohm coax over to the transmitters being tested.

This power measuring device can be used in any 50-ohm coaxial line to monitor the actual power going toward the antenna. The swr in the line should be low, or near unity, in order for the calibration to be reasonably accurate.

Wide-range VHF-UHF Dipper

by Bill Hoisington



From 130 to 1300 MHz with transistors

After all these years of "grid-dipping" we find ourselves without a grid; so it just becomes a "dipper." To retain the prestige of a hyphenated name we can call it a "dipper-generator." Most grid-dippers have been used as generators, but this one has built-in modulation, variable input-output coupling, controlled Q, and several other interesting features. Best of all, it goes all the way up past 1 GHz.

When this little unit is completed it may be used as a dipper for determining the resonant frequency of VHF and UHF circuits, as an indicating frequency meter with an adjustable Q-multiplier, a field strength meter and modulation monitor, a sensitive regenerative receiver, or a CW and MCW signal generator. You can also use it as a harmonic monitor or as a frequency transfer unit from one transmitter to another.

Several circuits must be considered when building a wideband instrument such as this. For example, you should change circuits around 100 MHz and again at 600 MHz, give or take a few hundred. Below 100 MHz coils are good; from there to 600 MHz you can use quarter-wave resonators, and after that the half-wave job becomes rapidly the best method, up to 1300 MHz.

Plug-In RF Heads

I have made no attempt to cover the complete range from 130 to 1300 MHz with one oscillator. By using plug-in tuners, you may vary the components to suit the frequency. On 50 MHz, for example, you may use a low-cost transistor, a coil, and 25 or 50 pF capacitor. From 100 to 600 MHz you use a better transistor, a quarter-wave strap, and a 10 or 15 pF capacitor. In the microwave region up to 1500 MHz, you use the best transistor you've got, half-wave lines, and a small butterfly capacitor of 3 to 5 pF.

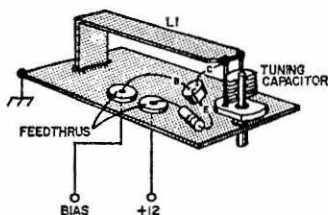


Fig. 1. Basic VHF/UHF oscillator circuit.

If you break the circuit at the right point, it simplifies things—then the two halves may be connected through a miniature 7-pin socket and plug as shown in Fig. 2. All four leads are reasonably dead to rf. You can leave out some of the audio if you like, but it's very handy to have a modulated signal. If you're running triple or quadruple conversion, it's nice to know by its modulation which is the signal and which might be a birdie. As far as dials are concerned—it makes calibration and reading a lot easier to have only one band or range per dial.

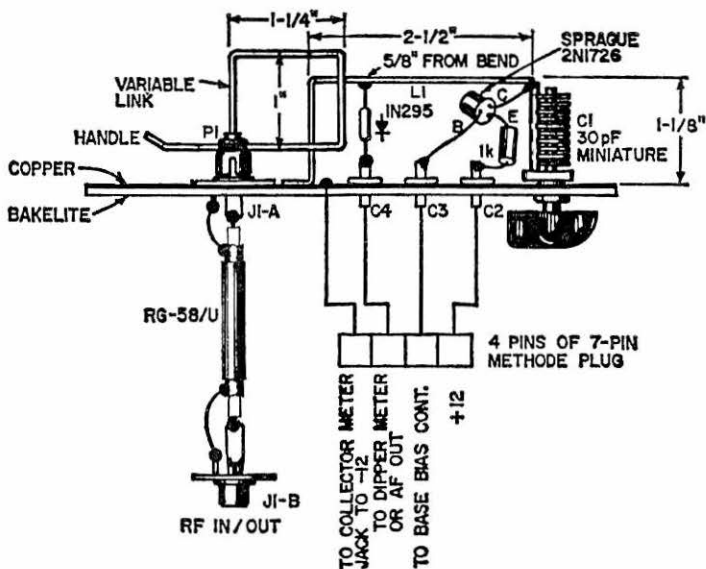


Fig. 2. 130 to 300 MHz tuning head.

130 to 300 MHz Oscillator

Figure 1 shows the basic quarter-wave circuit; Fig. 2 the complete rf unit with control, af output, and modulation.

The circuit itself is very simplified, as seen in Fig. 1; there being only one inductance (L1) and no choke coils. This should make for a flat-tuning oscillator without power dips as it is tuned over a 2 to 1 range in frequency, and it does just that. With a 2N1726 in the circuit, there is a smooth power output curve from about a volt of rf at 130 MHz down to about one-half volt at 300 MHz.

The rf coupling jack J1 couples the rf energy both in and out. This is because L1 acts as either a detector resonator or an oscillator resonator, as required. Actually this rf jack can be used as shown in Fig. 2. P1 is a variable link to L1 and is plugged into J1; J1A has a few inches of cable between the white ABS plastic front panel and the copper-clad Bakelite subpanel. Because the phono plug is rotatable, a nice variation in rf coupling can be obtained. The coax cable and J1B get the

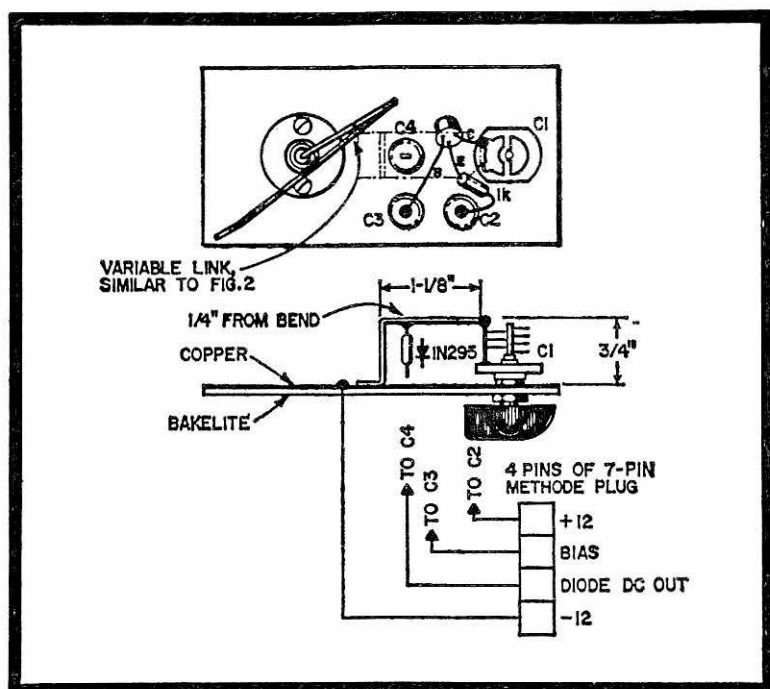
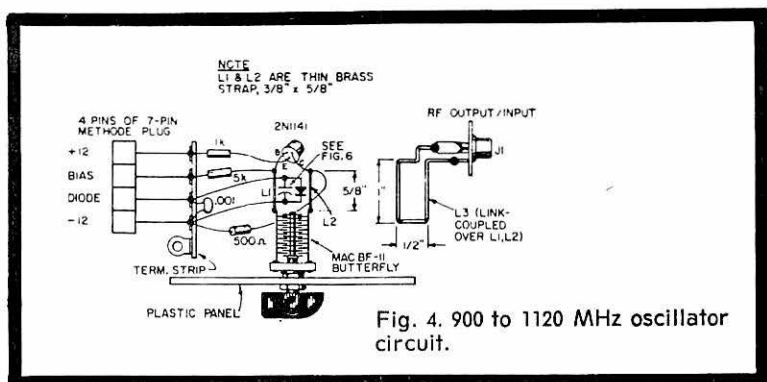


Fig. 3. 300 to 600 MHz oscillator with variable link.



rf out to the front panel for easy use with antennas, probes, cables, etc.

The emitter goes to a 1K resistor then through a coaxial bypass capacitor which gets the dc in and out and leaves the rf behind. These feedthrough-type bypass capacitors are very necessary—do not skimp on this item.

300 to 600 MHz Unit

Figure 3 shows that this unit is essentially the same as the last, except for dimensions. I used a 2N1141 here, though many others will work too. It tunes smoothly from 300 to 600 MHz; use the variable link feature as in Fig. 2.

900 to 1100 MHz

For this frequency range we need a little different approach. From Fig. 4, we can see that we now have two half-wave lines on which low-voltage points can be found to attach the base and collector resistors. Most of the quarter-wave portion of the lines on the transistor end are actually inside the case. The places where the base resistor and the 500-ohm collector resistor are attached to the half-wave lines can be found, or checked, by watching the rf meter and touching the lines with a pencil. At the proper point no change occurs in the rf output; sometimes it even increases.

The diode circuit of Fig. 5 is not ideal but it works. I have several of these around and they work very well for detecting 1296 MHz energy. Even ordinary hookup wire will support the assembly of Fig. 5 about 1/4 in. below the rf lines; you will soon

find the best spot with the unit oscillating. The rf input jack and associated loop (L3) are fastened so that L3 is in place over L1 and L2, and its coupling can be varied in a semifixed fashion.

As a dipper, the circuit is still working fine—also as a signal generator. It also serves as an rf detector; but as the frequency gets up into the microwave ranges, it is not quite as good as tuned rf detectors.

Ideally, you should use the dipper on microwaves as a modulated generator and couple it into the unknown circuit; then a probe attached to another tuned detector should be coupled into the unknown circuit. There are quite a few variations using the dipper as an oscillator that you will find useful if you use a little ingenuity.

In the microwave detector line, my experience indicates that the plunger-tuned coax cavity line is the best, the tuned trough line next, and the circuit of Fig. 6 next best. As a dipper, generator, and regenerative receiver it is still good at 1296 MHz. Just to check, I plugged an antenna into J1, put an audio amplifier across the diode and copied a small transistor oscillator across the room. The base bias control works as a very smooth regeneration control. Smooth regeneration, as we will see later, is very important for maximum sensitivity when looking for harmonics and weak signals.

1200 to 1500 MHz Unit

Figure 6 shows the 1.5 GHz unit; I have used this circuit for many months as a dipper, variable-frequency generator, modulated-oscillator source, and as a regenerative receiver for 1296 MHz. In this circuit I used a negative dc grounded-collector return. Don't short the base plate to the modulator base. Note that one end of the diode is tied to the base plate; this lead is brought out as the -12V lead. You can also use it ungrounded as in Fig. 4—you can use a fifth lead in the 7-pin plug and keep the diode isolated from the -12V. Suit yourself;

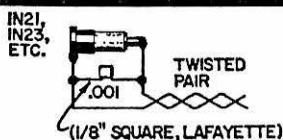
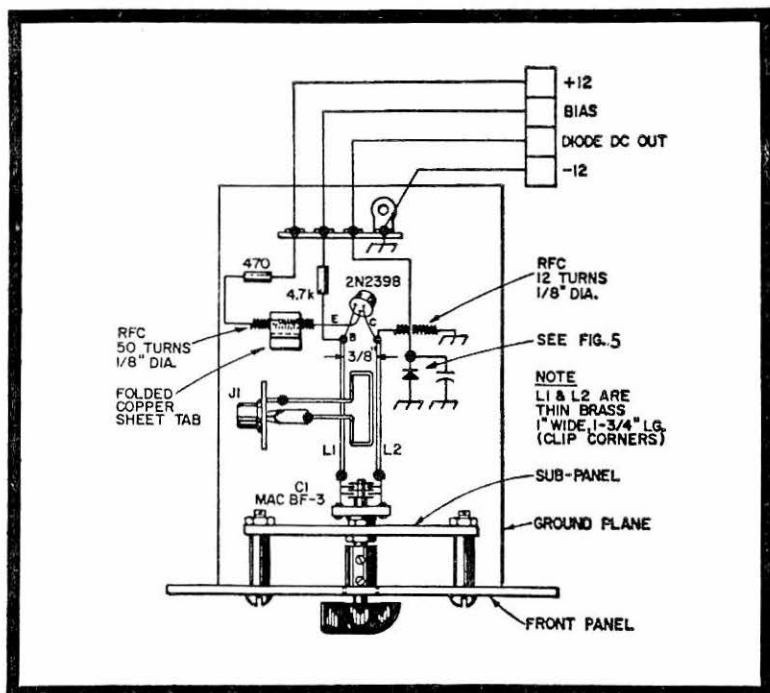


Fig. 5. RF detection loop for half-wave oscillators.



just remember that all units have to use the same leads, as they all plug into the single modulator rf unit.

I had to put a choke in the cathode lead on this one, and tune it (the choke) with a piece of copper foil. A choke was needed in the collector lead too; after all this is the L-band microwave region.

The rf input jack J1 is mounted on a Bakelite upright. Be careful of vertical metal pieces attached to the base plate; they only need to be a couple of inches long or so to become Marconi antennas on 1296 MHz. Bring the base resistor and the collector choke away from the lines in a perpendicular fashion—it helps.

The total length of the diode and its two leads, from ground to the tiny 0.001 μ F capacitor (C2) is about 1½ in.; it is spaced about 3/16 in. from the ground plane. The bottom edges of the lines are about 0.5 in. from the ground plane.

The transistor presently in the unit is a selected 2N2398; about half of the dozen or so I have here go to 1300 MHz, a couple go to 1400, and the rest to 1100 or 1200.

Don't be alarmed that L1 and L2 are longer than those of Fig. 6; the smaller butterfly capacitor does that. You can make a choice as to capacity, length of brass, and desired rf range. You can use a 5 or 10 pF capacitor for C1, shorter lines, and tune over 1500 MHz.

Modulation and Control

Figure 7 shows the circuitry for bias control, modulation, and audio. Don't let it scare you. It's just the same old deal of doing what has to be done for control purposes, and from then on just turning the knobs to get what you want.

I have found that a very good plug and jack can be made by using an ordinary 7-pin socket and a Methode 7-pin Bakelite plug. Unfortunately, I have never found a miniature tube with a Bakelite base; they are always made of glass, so you will probably have to buy the 7-pin plug.

The -12V lead goes to the collector meter jack and then to the -12V connection of the power supply. This puts the rf panel ground at -12V and the audio af panel at +12V. Of

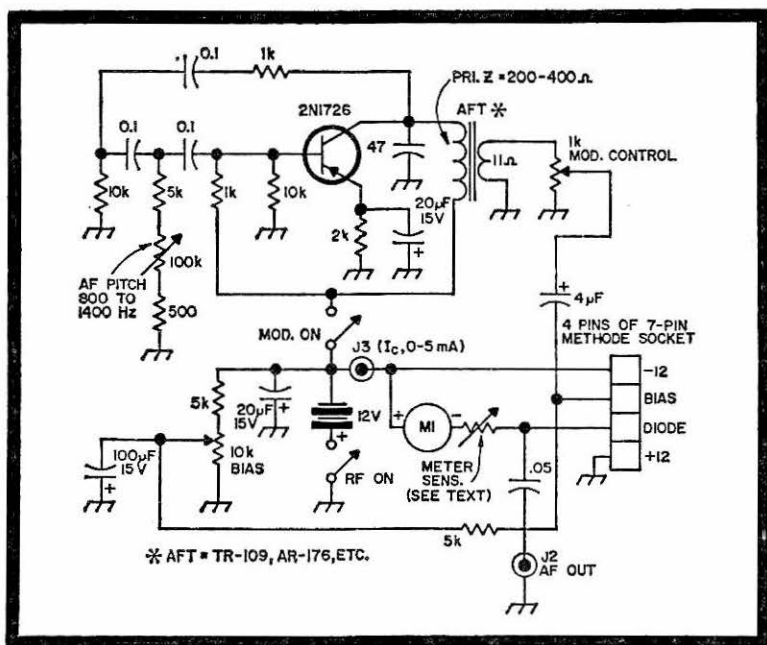


Fig. 7. Power control, modulation and audio circuitry. This circuit is used with all the rf heads.

course, you don't have to ground the +12V on the audio panel; I just have that habit.

The base return goes through a 5K resistor and then to the bias control potentiometer. The diode dc/af output goes to af jack J2 and the meter M1 through the meter sensitivity control. This potentiometer is selected to suit the meter; I have used a 10K unit with a 500 uA meter. Note that part of this resistor should be used when af output is desired; otherwise the meter shorts out the af.

Audio Modulation

You might think that just about everyone knows how to build an audio oscillator. Mine did oscillate, but the tone! And the waveshapes, hoo-boy! I used an af transformer with the collector on one side and the base on the other. So, once again to the handbooks and once again practically zilch. I did get the idea for a phase-shift oscillator out of one of them, even if the circuit didn't work at first. After considerable experimentation, I can recommend the circuit shown in Fig. 7. It works! In addition, the modulation may be adjusted to exactly 1000 Hz. This is very useful as many microwave test amplifiers have built-in narrowband af audio filters centered on 1 kHz. There is also a modulation gain control. This helps if a nice tone is desired.

Almost any small transistor output transformer will do the job for the af transformer, but don't go over 400 ohms impedance in the collector winding. Note the 1K resistor between the collector and the phase-shift network; this reduces feedback to the base and may have to be increased or decreased depending on the gain of your transistor at 1000 Hz.

I usually run the rf current (collector dc) between one and two milliamperes with the 2N1726 transistors; other transistors may take more. A No. 48 bulb in the collector lead may save you a \$3 transistor. With the 2N1141, the rf output keeps climbing up to 4 or 5 mA collector current. You will readily find the best place to operate. When the collector current keeps climbing and the rf output starts to drop, back off!

Dipper Operation

As a general rule, dipping is easier in the VHF region; and it gets more difficult as you go into the microwave region. On

HF, you couple one coil end on to the other; on VHF you bring it near; and on UHF you have to work to get the necessary coupling or use a probe.

With nothing near the dipper, swing the dial through the range to make sure it has no dips of its own. The VHF/UHF units without chokes described here do not generally have such dips. Unwanted dips can be caused by chokes, resonant feed-wire lengths, metal supports, and rf links and cables among other things.

When you do get a dip after coupling to the unknown circuit, be sure and change the resonance of that circuit for a final check while watching the dipper meter. If the test circuit is a tuned circuit, vary the tuning and see if the dipper will follow it—it should. If all else fails, use the dipper as a generator. Since it is very difficult to get the far end of a cable matched exactly over much of a frequency range, expect to find external dips in the dipper when using a cable.

Indicating Frequency Meter

Always keep the transistor plugged in and the base bias at zero so the diode is doing the work. When you advance the bias, collector capacity will cause the dipper frequency to change a little—more with some transistors than others.

For finding a weak signal, you can use regeneration by turning up the base bias, but watch out for slight frequency changes. This regeneration can be very handy for finding weak oscillators or hard-to-find rf energy. Use the rf input loop with care; the least coupling is the best. Remember that some cables and terminations will detune L1.

Field Strength Meter and Modulation Monitor

The first part is obvious; use a small antenna or probe, get some signal in, and go ahead. Do not use any base bias to start with. If you are working with a very weak signal you might have to push the bias up for regeneration.

The modulation monitor is nothing other than the simple system of diode detector, transistor amplifier, and padded earphones.

Regenerative Receiver

Plug an audio amplifier into J2, Fig. 7, advance the bias control, and tune. I have heard several UHF TV stations from

75 miles away, so it is really sensitive. One nice feature of this circuit is that the regeneration turns into oscillation very smoothly. Stability is good, too.

To transfer signals from one transmitter (A) to another (B), just tune in A, then shut it off; listen for B and tune it in. That's all. Harmonic monitoring is easy; just tune over the suspected range in the regenerative condition. It is particularly good because only one frequency is present in the receiver. This is not the case when using a superheterodyne receiver for monitoring harmonics.

Signal Generator

One of the big features of this circuit is the presence of an rf meter right in the proper place circuit-wise. The modulation also helps, especially when running triple or quadruple conversion in a receiver. The modulation control is very convenient; at full on, it spreads the signal across 20 or 30 kHz on a selective receiver. For checking a difficult-to-get-at circuit, use a cable and probe, either capacitive or inductive, to get the signal into the unknown circuit.

I often use one of these units for antenna and receiver tests. I just plug a little two-element beam into the rf jack and set it out away from the shop—often one or two hundred yards away. There is nothing like tuning up preamps with your antenna system connected. For antenna tests it is used in reverse.

VHF Emitter Dipper

by John Boyd

One of the most useful pieces of test equipment is the grid-dip oscillator, or GDO. Besides being relatively inexpensive, it is particularly versatile. Need an indicating absorption wavemeter? The GDO will do that. How about a modulated signal source?

Since the grid-dip oscillator, by virtue of its time-honored name, calls for a grid circuit, it seems a shame to blaspheme it with the introduction of a "gridless" semiconductor. Somehow, the term "emitter-dip oscillator" just doesn't have a good ring to it; so, in this project I'll go on referring to the meter as a GDO—and if you have to assign a word for each letter of the abbreviation, you can think of the dipper as a "great dip oscillator" and we'll both be happy.

Every item used in the GDO (see photo, Fig. 1) was selected with an eye toward the average home builder. There

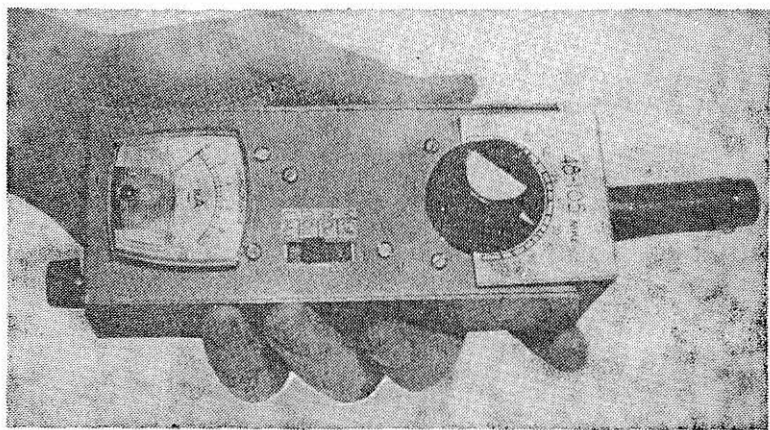


Fig. 1. Transistor GDO.

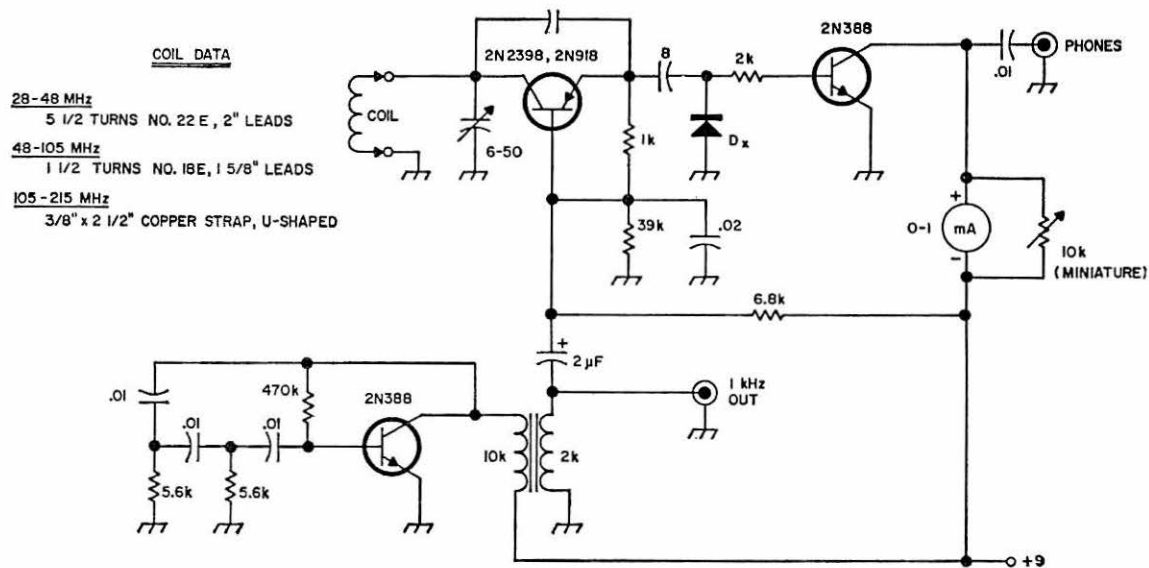


Fig. 1. Circuit diagram of the great dipper. Note that although the 2N2398 is a PNP transistor, the 2N918 is NPN, and if used as the oscillator transistor, problems would arise with voltage polarity. The diode D may be almost anything that you have available. The 1 pF gimmick capacitor consists of 1½" of twisted wire.

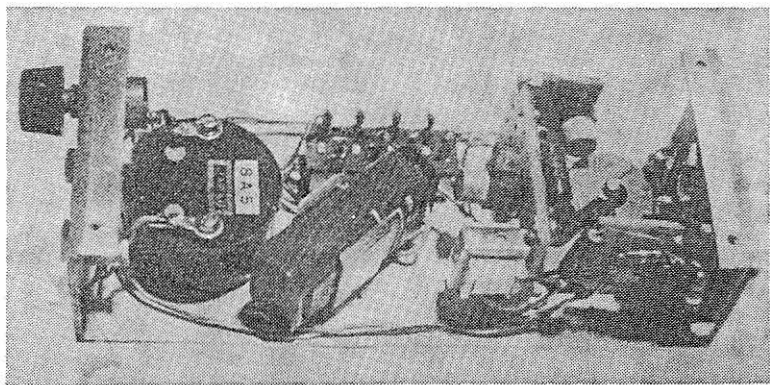
are no parts which must be specially purchased from the West Indies Export Company or the like. Nearly all the parts, except for the meter, miniature pot, and mode switch, were obtained from the junkbox—or rather, from several junkboxes. If you insist on buying all new parts, the total cost of the project will be about \$20.

Circuit Description

Emitter current in transistor Q1 (see schematic, Fig. 2) decreases when the tuned circuit C1-L1 is in resonance with a nearby circuit. This decrease is easily seen by the dip of the indicating pointer.

When switched to the diode position, B+ is removed from the oscillator and the incoming rf is rectified by diode D_x; the voltage developed across the 2K resistor is amplified by the meter amplifier and monitored by the 0-1 mA meter. In switching to the signal position B+ is removed from the meter amplifier but applied to the modulator, and a 1 kHz tone is available from one of the output jacks. In the modulated oscillator position, B+ is reapplied to the oscillator, and the oscillator is modulated by the 1 kHz tone.

Like a patchwork quilt, this GDO was built using circuits from already published articles or books, and then modified as necessary. The whole circuit is composed of three separate entities—oscillator, meter amplifier, and audio tone generator. The circuit is not particularly critical, but lead



Internal construction of the great dipper. The modulator and oscillator boards are to the right—the oscillator transistor is mounted right next to the coil jacks.

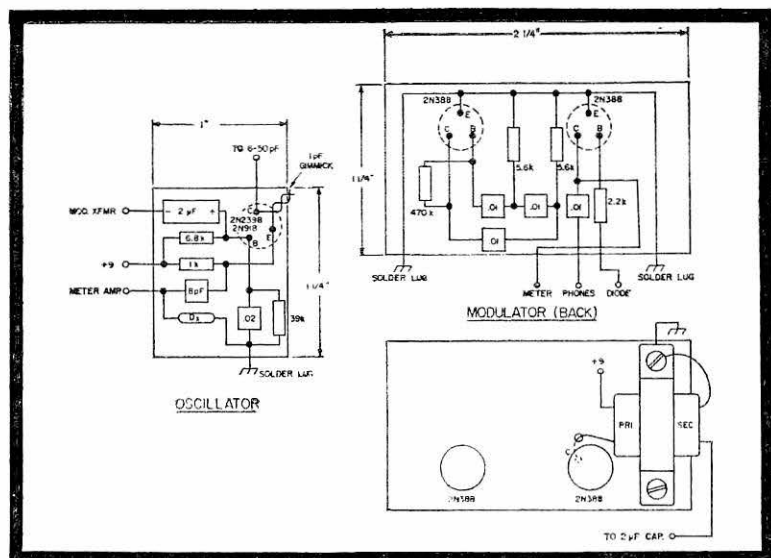


Fig. 2. Layout of the two circuit boards used in the great dipper. Although two boards were used in this case, the circuit could be easily adapted to one board, and even to printed circuitry.

lengths and dress in the oscillator must follow good VHF practice if stable VHF oscillation is to be maintained.

Quite naturally, when I discovered that the GDO would not oscillate satisfactorily over the entire range from 2 to 200 MHz, I juggled values so that it would oscillate well at 220 MHz (for tuning frequency doublers to 450 MHz); then I tried to get as low in frequency as possible. Oscillation was vigorous to about 20 MHz. Coils and scales were then made to cover the respective ranges. If you don't do any homebrewing on the VHF bands, perhaps you will find it necessary to change the value of the emitter-collector feedback capacitor, and to juggle the emitter and base resistor values in order to sustain oscillation at your desired frequencies.

Construction

I used perforated phenolic (Vectorbord) mainly because I wanted to experiment with component values; however, a printed circuit would be just as good, though it would be considerably more expensive and hard to justify in such a one-of-a-kind project. It can be seen from the photograph that the

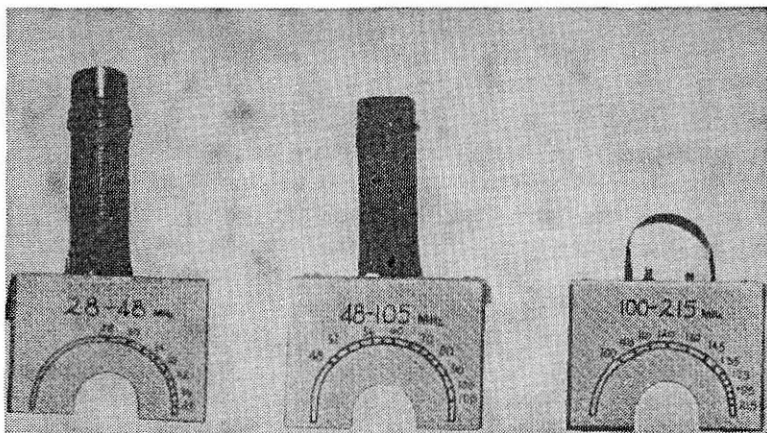
meter amplifier and audio oscillator are built on separate boards. This is because I built several different amplifiers; the layout would look neater if they were on the same board. Positioning of the rf oscillator and capacitor C1 as shown in the photograph is recommended, but the placement of other parts is not critical.

Fiber-glass board is used as an insulator for mounting the banana jacks and plugs. It cuts and drills easily and appears to work fine. Three banana jacks were used, the third jack being used merely to provide mechanical rigidity. It could also be used, if necessary, to shunt additional capacitance across the emitter and collector on the lower frequencies.

Because a shear and a brake were available, I constructed my own chassis, consisting of two U-shaped pieces of heavy-gage aluminum.

Using the GDO is a breeze, for it fits the hand very comfortably; if placed on the workbench, it doesn't roll off each time it is bumped. The completed case ($1\frac{3}{4} \times 2\frac{1}{2} \times 6\frac{1}{4}$ in.) is exceptionally rigid and imparts a reassuringly solid feel when handled. Commercially available miniboxes could be used if you don't have facilities available for rolling your own, of course.

In building the rf oscillator, keep all the rf leads as short as possible; especially the short lead from C1 to Q1 and from circuit ground to chassis ground. It was found that false dips could be completely eliminated if a copper strap $\frac{1}{4}$ in. wide



The three plug-in coils for the **great dipper**. Three ranges cover from 28 to 216 MHz. The second harmonic of 216 MHz may be used for tuning up 432 MHz converters and such.

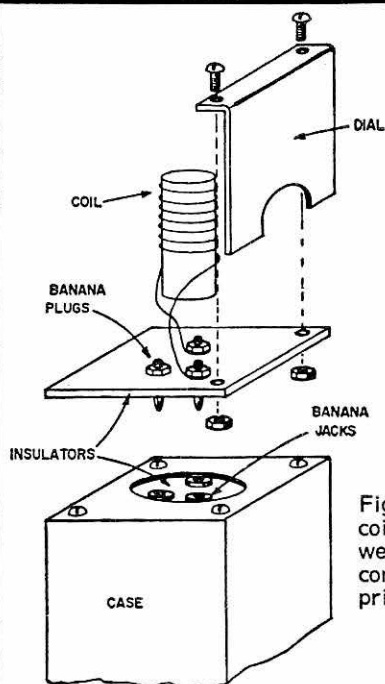


Fig. 3. Construction of the plug-in coil assemblies. The coil forms were made from the plastic containers which hold Polaroid print coater.

was added from the capacitor ground lug directly to chassis ground. Apparently the ground on the variable capacitor C1 is not quite good enough at frequencies above 100 MHz.

Various transistors were tried in the oscillator; the PNP-type 2N2398 was found to be a good performer, as was the NPN-type 2N918. However, the use of the NPN-type could lead to problems with battery polarity. Capacitor C2 is a 1½ in. length of twisted wire positioned near the collector lead of Q1.

To keep cost low, a 0-1 mA meter was used in conjunction with a simple meter amplifier. If you happen to have a 0-50 uA meter lying in the junkbox, that would work equally well, and the circuit could be simplified accordingly. Several circuits were built for the meter amplifier; the one chosen was a compromise between cost and performance. A germanium transistor was used because it requires less voltage to turn on. Leakage is low, the pointer of the meter resting just off zero when no coil is in place.

A transistorized audio tone generator is coupled by a 2 uF capacitor to the base of the oscillator transistor for

modulation. This modulated oscillator allows the GDO to be used as a versatile signal source. An output jack is included on the panel to allow the 1 kHz tone to be used without turning on the oscillator. The deceptively simple circuit was taken from June 1966 73 Magazine.

There are a couple of components which not everyone will want to duplicate. One, the subminiature 10K pot with SPST switch, was chosen because a very limited amount of space was available; if the unit is built on a larger chassis, the more commonly available Midgetrol could be used. The other, a four position switch used to select the desired mode, is a 29-cent variety available from Lafayette or Radio Shack. It has a peculiar switching arrangement; if you duplicate this project, several hours of experimenting could be eliminated by following the pictorial diagram included here.

A disadvantage of this particular switch is that the meter does not indicate in the modulated oscillator position.

Using individual scales on each plug-in coil assembly greatly enhances scale legibility, reducing the chance of reading error and speeding frequency identification. This scheme, however, is not original. It was described in a 1957 issue of Short-Wave Magazine, and is currently being used on a commercial GDO. It requires little additional effort to build the coil assembly in this manner and is well worth that extra effort. For want of anything better, the coil forms were made from the plastic tubes which contain the film coater supplied with each roll of Polaroid film.

Lastly, ease of tuning is accomplished largely through the use of a 1 in. diameter skirted knob. Small knobs are simply too difficult to use comfortably.

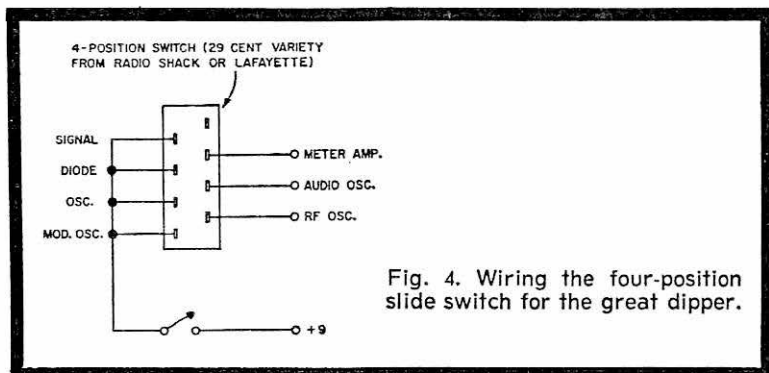


Fig. 4. Wiring the four-position slide switch for the great dipper.

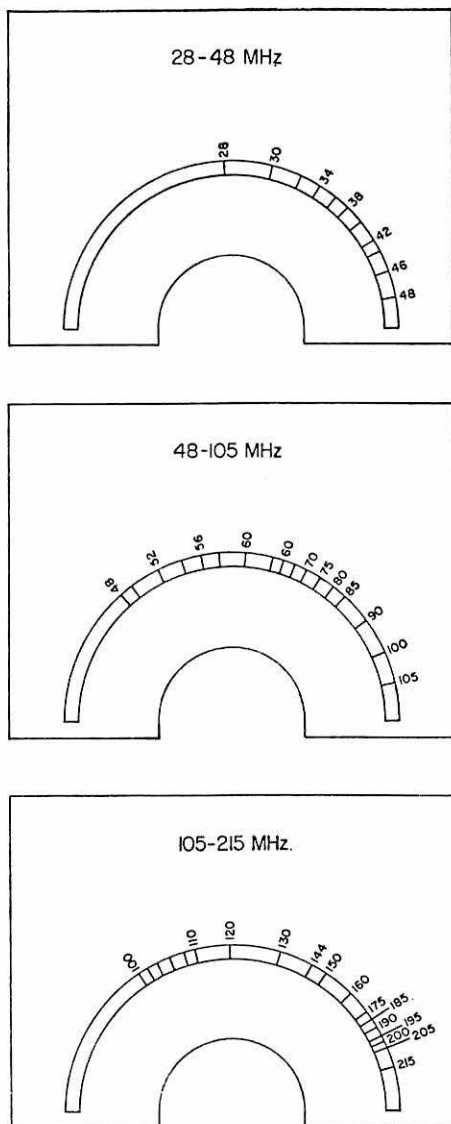


Fig. 5. Full-scale dials for the great dipper. If the construction shown in the photographs is followed closely, the calibration of these dials should be within several percent.

Calibration and Operation

It is best to calibrate this GDO by listening for the oscillator, modulated by the 1 kHz tone, on a general-coverage receiver. An alternate method is to use another GDO, placing one in oscillate and the other in diode, tuning for either peak or dip. The scales which were used on this GDO will serve if parts and layout are followed closely.

To use this unit as a dipper, place the mode switch in oscillate, and place the dipper coil next to the coil under test. The turns of both coils should be parallel, and not at right angles to each other. To keep from pulling the oscillator frequency, keep the two coils separated as much as possible, while still maintaining a meter dip. This assures that dial accuracy will be kept high. If a coil is inaccessible, twist a pair of wires together, forming a two-turn coil on each end; slip this coupling link over the two coils. Keep in mind that a coil, when it is in a circuit, may not dip at the same frequency as when it is out of this same circuit.

Conclusion

This is one of those pieces of test gear that makes you wonder, when you finally get one, how you ever got along without it. Not only is this GDO rugged and reliable, it is also inexpensive to build. The meter exhibits a deep positive dip and no false dips are evident. It has become indispensable to me. Some hours were spent optimizing values and layout for many particular needs, but the final result justified this effort. If you're skeptical, plug in the soldering iron and see for yourself!

The Dip Light

by Ed Babudro

Have you ever wondered how the grid dip meter got its name? I think it is self-explanatory to a certain extent, indicating that there is a meter in the grid circuit of a tube and that it measures the dip in current that occurs as the energy is absorbed when the oscillator tunes to the same frequency as the circuit under test. The name is all right as long as you think in terms of the tube circuit, but in recent years we have been seeing circuits using transistors and tunnel diode oscillators taking over. In other words, no grids.

So now the name has changed to "dip meter," which is fine as long as you have no objection to the meter part. As I see it, the meter has done a very good job in the past on this instrument, but nowadays we can come up with devices not limited by the constraints imposed on the people who first developed the grid-dip meter. Think of a pilot light bulb, for instance. How much better it would serve the purpose, since you would not have to concentrate on it to see a dip as you would with the meter. Many times as I stared at the meter (which happens to be at the opposite end from the coil), I would find that I was getting no dip simply because I had inadvertently moved the coil away from the circuit under test.

A light bulb is much more obvious than a meter needle, and in this use you really would not need the precision that a microammeter gives. All you really want is a dip. A light bulb is just not sensitive enough to read microamperes. But what if you were to help it with a couple of transistors? This is the crux of the dip light shown in Fig. 1—the little devil that will do everything that a grid-dip meter will do, only better. And it can be built more cheaply to boot.

Construction

You can use regular coax connectors for the coils and build the latter on a stub of coax about 3 in. long, with the

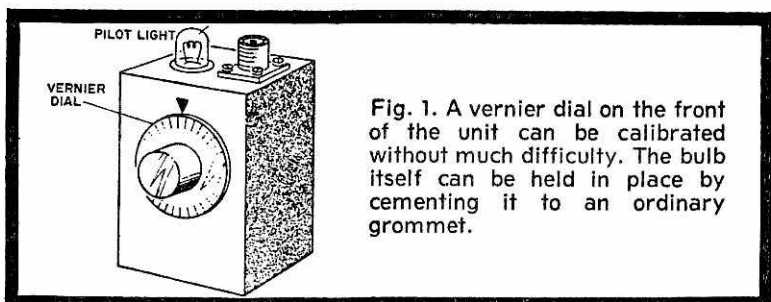


Fig. 1. A vernier dial on the front of the unit can be calibrated without much difficulty. The bulb itself can be held in place by cementing it to an ordinary grommet.

connector at one end, and the outer cover and shield peeled back as shown in Fig. 2. The coil is wound on the plastic core, soldered to the center conductor and shield, and then covered up with GE crude rubber cement, which is quite soft and flexible even after having cured.

The indicator lamp should go somewhere near the coil, where you can see it and the coil at the same time. For the frequency readout, I used a small calibrated vernier drive. You'll find this easier than making your own dial, and you can use a chart or set of curves to correlate frequency with the calibrated increments.

For the tuning capacitor, use an APC with a $\frac{1}{4}$ in. shaft. Mine had some plates removed, but I would guess it to be about 30 pF.

The oscillator circuit happens to be my pet one, but since it is not critical, you could use your own circuit. It occurred to me that one could open up one of those two-dollar modules sold as FM wireless-microphone broadcasters. At least one that I know of is not encapsulated in epoxy. I built my own (Fig. 3) with GE9 transistors and have no trouble getting this little gem to oscillate up to 120 MHz.

Capacitor C1 should be chosen to oscillate down to the lowest frequency to be used. My unit worked well with a 55 pF

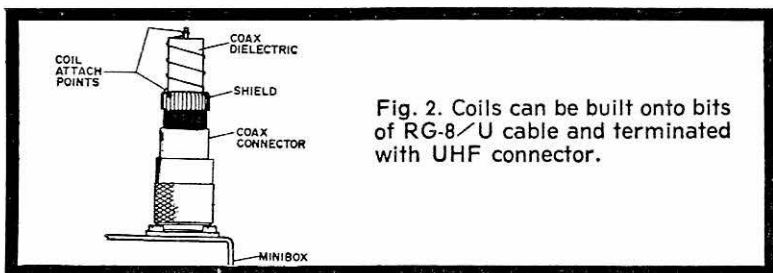
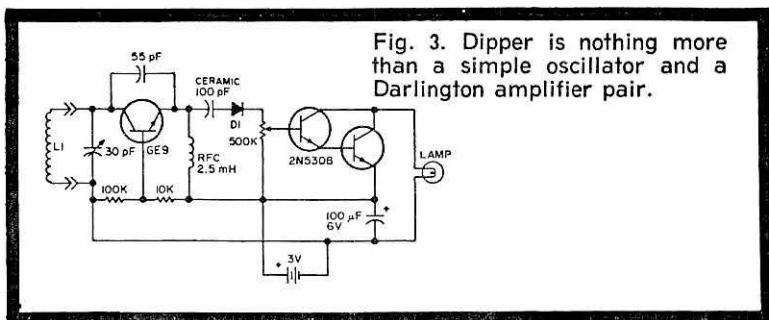


Fig. 2. Coils can be built onto bits of RG-8/U cable and terminated with UHF connector.



capacitor. Resistor R1 should be about 100K initially; then, when you have finished building, you can replace this with a 500K temporarily. Adjust this for a good indication on your lamp (I set mine for maximum rf, but don't know how good this might be for the transistor), and then replace with a fixed value to correspond with the setting of your pot. The lamp amplifier is a Darlington circuit to provide a better load for the diode circuit, but you could use a one-transistor circuit almost as effectively.

Be sure that you use high-gain transistors in either case, though; they should be medium-power "driver" types to handle the current required to light the lamp, which should be a low-current one such as the No. 48 or 49 bulbs (coded with pink beads). Use two penlight cells for power and you end up having a really versatile instrument.

Plotting the Frequency

Making the frequency curves should be a simple enough matter using "science" graph paper and an accurately tuned receiver. Simply tune the receiver to the frequency that you need, then find it with the frequency control of your dipper. First, find the highest and lowest frequency that the instrument will cover, and mark this along the side of your graph. Mark the maximum number of divisions of your dial along the bottom of the graph. Then spot a few frequencies more or less evenly spaced between the maximum and minimum, and draw your curve to touch all the points. Voila! You have a curve for one coil. Repeat this for the others. This method is good because if you ever wish to make an extra coil, you simply make an extra frequency curve for it and do not have to alter your instrument at all.

FET Gate Dipper

by John Aggers

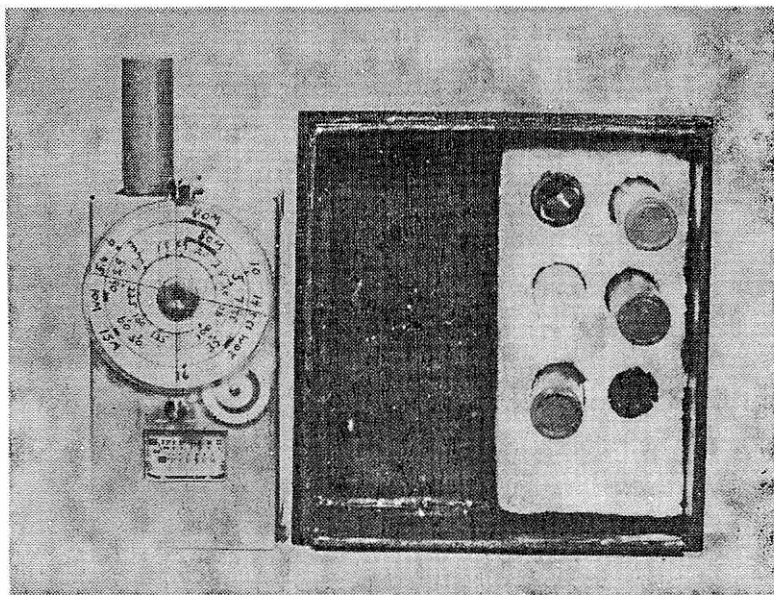
Possibly you now own a grid dipper, but is it small, easy to handle, and cordless, making it completely portable? If not, you will want to build this gate-dip meter. The cost is extremely low—only about \$7. All parts are readily obtainable and construction is simple. The plug-in coil forms, using battery plugs and polystyrene tubing, are easy to make.

The Circuit

An MPF 102 FET is used in a modified Colpitts circuit. Except for the No. 1 coil, where a choke is used, the B+ is fed to the centertap of the coil. This is necessary to obtain a fairly constant gate current as the oscillator is tuned to its end frequencies. Drain current varies from 4 to 1 mA proceeding from 225 to 1.7 MHz. At the same time, the gate current varies from 20 to well over 50 μ A.

From this, it is apparent that the stronger the oscillations, the smaller the drain current and the larger the gate current. In gate-dip operation, as power is drawn from the oscillator, the drain current will increase and the gate current will decrease or dip.

Limited wavemeter operation, obtained by switching off the B+, is accompanied by a slight shift in calibration. When the circuit picks up rf, the FET suddenly goes into oscillation using the rf as its battery. Thus, the amount of rf picked up must be large enough or there will be no oscillation and no meter indication. However, despite these deficiencies, it is still considered a useful mode of operation and for that reason has been included. It is only necessary to wire the sensitivity control so that the resistance is maximum when the switch is in the off position.



The little gate dipper with spare coils.

Construction

A natural-finish aluminum minibox ($4 \times 2\frac{1}{8} \times 1\frac{5}{8}$ in.) is used for the meter case. The variable capacitor came from an old transistor radio and measured $1\frac{3}{8} \times \frac{1}{2} \times 1$ in. The shaft was already squared and tapped for a small screw. Since those listed in the catalogs have a plain or flat shaft, you will have to use a collar with setscrew, or drill and tap the shaft. The trimmer capacitors are not used and should be removed.

To make the coil socket, you will need three pin receptacles from an octal socket, two pieces of $\frac{1}{8}$ in. Plexiglas approximately $\frac{7}{8} \times \frac{3}{4}$ in., and one battery plug for a pattern. The pins of the battery plug form a triangle. I shall refer to the holes at the base as the outside holes. Drill holes in one piece of plastic to match the pins of the battery plug. Match the two pieces of plastic, clamp in a vise, and drill the two outside holes in the second piece. Bend the lug part of each socket pin to a right angle. Slip one over each outside pin of the battery plug. Using this as a jig, solder the lug portions to the stators of the variable capacitor. Remove the plug, and the pieces of plastic should fit down over the variable capacitor. The lug

part of the center socket pin is brought out between the two layers of plastic.

File a small notch in the bottom piece to accommodate the lug. Before cementing the two pieces together and to the frame, make each hole slightly larger than the diameter of the socket pins. This will allow for expansion when the plug is inserted.

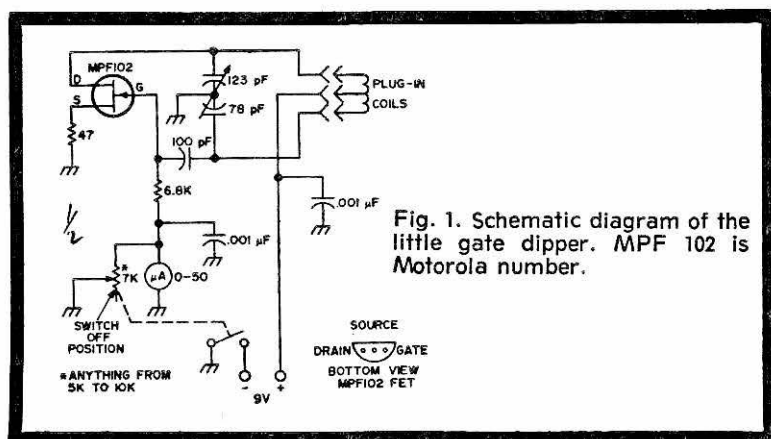
The dial is made of $2\frac{1}{4}$ in. diameter (by $\frac{1}{8}$ in. thick) Plexiglas. To give the dial a rough edge for good thumb traction, I heated an old gear wheel and rigged up an arrangement to rotate the dial against it. The gear should have rather coarse teeth and rotate with the dial, or you will create flat spots.

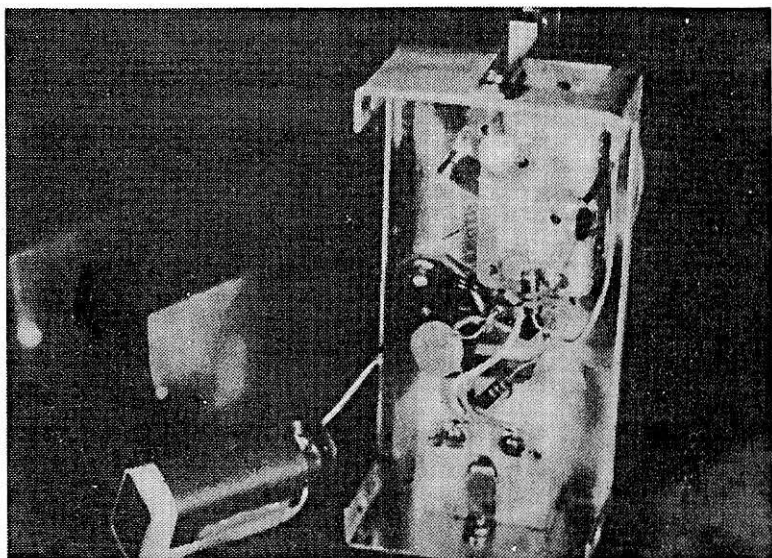
The variable capacitor can now be mounted in the case. Position it so that the top and sides of the dial will be just about even with the edges of the case.

The dial marker is mounted on square aluminum posts. The top post (2 in. long) has $1\frac{1}{2}$ in. of its length filed down to a $\frac{1}{8}$ in. thickness to reduce its bulky appearance. To make the hairline, scribe a line in a $\frac{1}{2}$ in. wide piece of plastic and fill in with a ballpoint pen.

The sensitivity control I used was already prepared for the knob shown. If you don't have one like it, use a dime-size pot and a setscrew knob. Any resistance from 5K to 10K will be fine.

Keystone light meters are available from Olson Electronics in a package of five (\$3.99) or Transistors Unlimited Co. (75 cents each). Some modification of the meter is





Meter is held against the front panel by a small bracket.

necessary. Remove the light cell and series resistor. Drill two holes (spaced $\frac{1}{2}$ in. apart) in the back of the case to pass 4-40 machine screws. For easy soldering, make sure the heads and nuts are clean and free of any nickel plating. The screws should be filed even with their nuts in order to make room for the battery. Solder the leads from the meter movement to the terminals, but be quick because the plastic case tends to melt in a hurry.

Wiring is just a here-to-there proposition, requiring no terminal boards or terminal lugs. The FET is soldered in place supported by its own leads. With reasonable care, you should not damage it. A battery holder was found unnecessary; however, it is a good idea to wrap a layer of tape or stiff fiber paper around the battery to prevent the metal case from shorting out the meter terminals.

Coil Construction

Figure 2 and the photo give the necessary dimensions and show the parts needed to make the coil forms. The battery plugs are listed in the catalogs to fit No. 482 and M3 batteries. The center pin should be filed slightly shorter to make the plug seat evenly in the socket. While you are at it, file the nickel

plating from the ends of all plug prongs. This will make for easier soldering.

Complete coil information is given in Fig. 2. However, a little explanation may be in order. The irregular method of winding the No. 2 coil is necessary to reach 85 MHz and still maintain oscillation. With 4 turns close-wound, the highest was too low. With the 4 turns spaced, oscillation ceased at the highest frequency. The 30 AWG silk wire was taken from a TV flyback transformer. The resistors in the centertap of the last three coils improve the meter's sensitivity slightly. They are mounted right next to the coil winding. With a slight groove filed inside the insulating sleeve, it should slip over the resistor.

The No. 6 coil is layer-wound as space permits and scrambled-wound the rest of the necessary turns. The top winding of all coils should end near the very edge of the coil

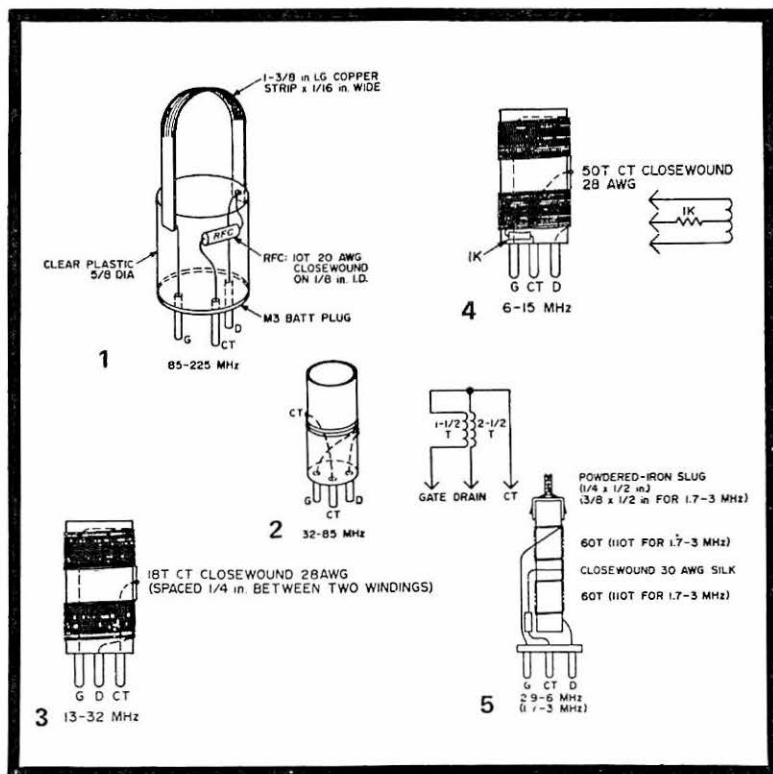


Fig. 2. Coil configurations for various frequencies of resonance.

form. This will make for easier coupling to a tuned circuit. After the coils are checked out, the insulating sleeves may be glued to the plug base.

Allow the glue to dry for several days before plugging the open ends of each coil with a small cardboard disc. The coils are painted with colored lacquers. Colored paper between the coil and the insulating sleeve will probably work just as well.

Calibration

For calibration purposes, you will need another indicating oscillator or dip meter. Operate it in the diode or wavemeter mode and loosely coupled to the gate dipper. I calibrated only 5 points on each scale plus any ham bands which appeared. Remember the dipper is not a precision frequency meter but something to get you in the ballpark.

Conclusion

The little gate dipper was checked against a well known commercial tube equivalent and, as near as I could tell, they were just about even. The battery should last for a long time because the current drain is extremely low.

VHF/UHF Wavemeter

by Lew Clark

Got an old field-strength meter around? It will make a dandy 220 MHz wavemeter.

First, remove all the "innards" except the meter on the front and the antenna receptacle on the top. This includes the phone jack on the rear and the magnet attached to the back cover with two screws (unless you enjoy having the wavemeter dangle precariously from some nook or cranny).

Slightly enlarge the rear phone jack hole, insert a nibbling tool and cut out the back. Take a piece of fairly stiff plastic, slightly larger than the hole you just cut, and glue it on the inside. Put the cover aside and let it dry. You can still get readings on the wavemeter without this plastic window in the rear, but only a small fraction of the meter swing with it installed.

In the vacant "pot" hole in the front panel, install a small 15 pF variable capacitor. Next, install the diode. I used a General Instruments DR303, but I am sure the more popular 1N34 or other VHF diodes will do as good a job. Coils L1 and L2 were made of very small (24-gage) plastic covered hookup wire. L1 is 1 turn, $\frac{1}{2}$ " in diameter; L2 is $1\frac{1}{2}$ turns, $\frac{1}{4}$ " in diameter.

My unit covers from about 150 MHz to well above 260 MHz. It should be stated here that some experimentation may be necessary with coils L1 and L2, depending upon what diode or capacitor is used. Use a dip meter for calibration. This unit has been tested with several different dip meters and the results are the same on each, so it works out well and will give you a "working piece" of equipment rather cheaply. It can be seen that with some experimentation this unit can be adapted to other bands of your choice.

Finally, with the weak signal emanating from a dip meter, I had very little success in picking up a reading using the



The 220 MHz wavemeter built from a Lafayette TM-14 Radio Field Indicator.

reinstalled antenna, but received excellent readings by placing the plastic rear opening as close as possible to my source of signal. With a stronger signal, the antenna can be used successfully to obtain readings without getting close to sources of rf.

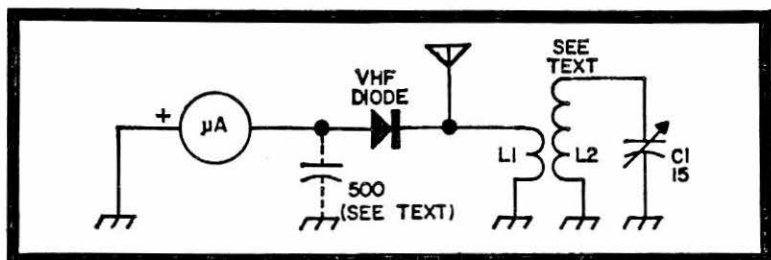
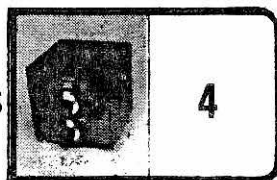


Fig. 1. Schematic diagram of the 220 MHz wavemeter. The coils are described in the text.

Regulated Power Source For ICs by Ed Raubb



Integrated circuits and some transistor units require low supply voltages at relatively high currents. While dry cells can meet the requirement temporarily, serious work and finished units are conveniently fed with line-operated supplies. The usual answer is a transistor regulated supply often more complex than the device it feeds.

The circuit shown in Fig. 1 was designed to supply an IC logic section of a business machine. It would make a compact low-cost supply for an IC keyer or for general experimental work.

Basically, it takes advantage of the 700 mV forward voltage drop of silicon diodes which varies only slightly with current change. A little time spent selecting individual diodes can provide a regulator for the exact voltage desired, including those values for which standard zeners are not available. Best of all, it can be assembled from parts commonly lying idle, thus freeing the regular bench supply for more demanding work.

The 4.1-ohm limiting resistance provides short-circuit protection for the 750 mA rectifiers, and is a necessary part of the filter circuit. A load-current variation from 0 to 50 mA causes a supply drop of just 1.65 percent. To improve regulation at higher currents, increase the size of the filter capacitor.

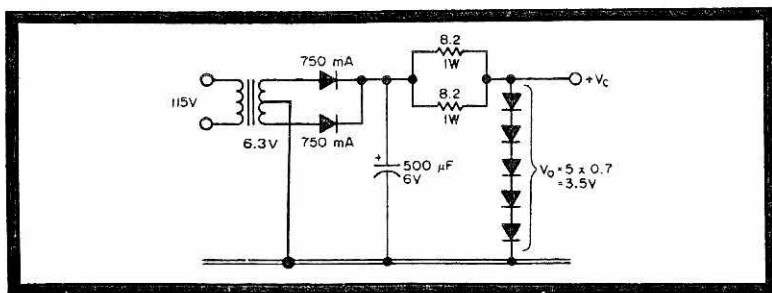


Fig. 1. Simple regulated power source for ICs.

A Solid-State 10-Minute Timer

by Walt Pinner

This 10-minute solid-state station timer is a simple economical, one-evening project whose application is only governed by your imagination. An indicator is illuminated by a set button and burns for 10 minutes before extinguishing, thereby reminding forgetful dispatchers to identify the station as required by the FCC. The unit, made up of 11 components, may be installed inside any transceiver or control console. The indicator lamp should be located where it is readily visible (such as adjacent to a red "transmit" light).

As shown in the circuit diagram (Fig. 1), the heart of the unit is a MOSFET, which gates an inexpensive SCR to turn on an indicator lamp (or, if you prefer, energize a relay). Voltage pulses are applied to the transistor and the RC timing circuit, 100-megohm low-leakage diode, and a 3 μ F 100V electrolytic capacitor.

When 6V appears at the capacitor, the FET is turned off, turning off the SCR and the indicator lamp. Pressing the set switch discharges the capacitor, recycling the circuit for an additional 10 minutes.

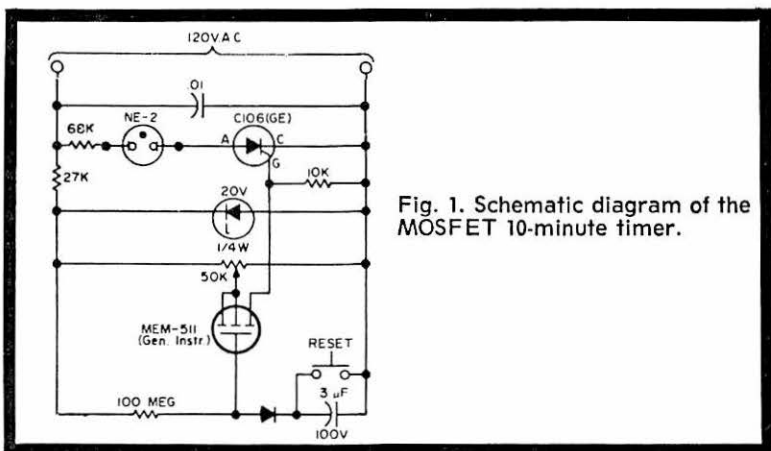


Fig. 1. Schematic diagram of the MOSFET 10-minute timer.

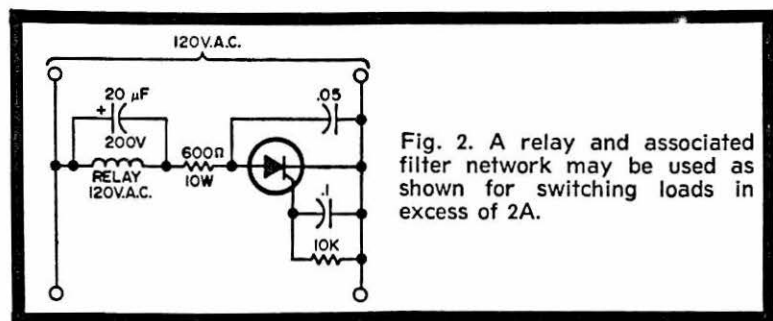


Fig. 2. A relay and associated filter network may be used as shown for switching loads in excess of 2A.

Because the circuit is line-operated, all components should be isolated from the chassis. In view of the high impedances involved, do not attempt to measure voltages, as any but the most sophisticated test equipment will load the circuit.

Caution: The FET is supplied with a shorting wire around its leads; this should remain in place until the transistor is soldered in the circuit.

Precise timing is adjusted with the 50K pot, which will compensate for component tolerances. Any neon panel

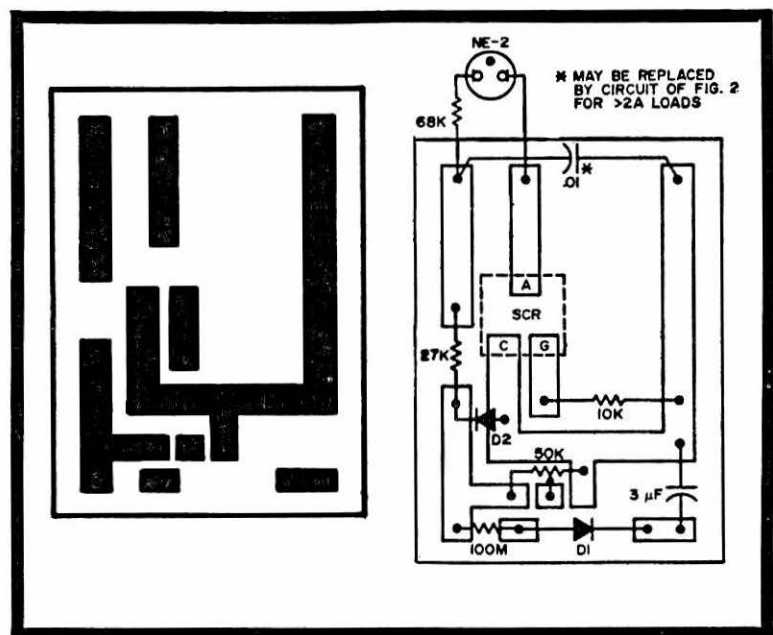


Fig. 3. Layout is shown actual-size alongside a composite view which gives component placement data.

indicator with a built-in resistor can be used in place of the NE-2 and 68K resistor. Color the bulb to contrast with existing panel lighting. Should you wish to power other dc loads up to 2A, merely substitute your choice for the lamp. For loads in excess of 2A, the NE-2 may be replaced by a triac or a 115V ac relay with a series 600-ohm 10W resistor and filter (Fig. 2).

The 600-ohm resistor limits the direct current through the ac relay to a safe level, and the 20 uF capacitor insures that the relay will remain on during the half-cycle the SCR is off. The reset switch may be unused contacts on your rig, such as spare positions on your 100 kHz calibrator switch. It may also be convenient to replace a control with one having a pull switch, thus eliminating the need for hole-drilling should you wish to preserve the original appearance of your equipment.

Wiring is not critical, and a circuit board (full size) is shown Fig. 3. After soldering, it is suggested that all connections on the board be cleaned with a solvent such as nail polish remover to eliminate leakage via flux, etc. The zener and low-leakage diode were obtained from surplus boards. The SCR is not critical, and any type with 120V ratings that will trigger at 0.8V is acceptable.

Test Probes

by Walt Pinner

The proper test probe for your VTVM, FET meter, VOM, or scope won't cost the usual \$12-\$19 if you are willing to spend an hour, a few cents, and follow the procedure below.

The usual stumbling block in homebrew probes is not the circuitry, but the hassles of obtaining a suitable housing or probe body. The common "Carter's Marks-A-Lot" felt-tip pen is one suitable answer. These felt-tip pens have an aluminum housing that is convenient to hold and large enough to house the necessary components. And when the paper label is removed, it even has a "professional" appearance when assembled. Obtain an old pen (new will also work, if you must), and disassemble as shown in Fig. 1. Any of the probes listed below may be assembled as the example in Fig. 2 (low capacity scope probe). The direct, low capacity switch—SPST—may be incorporated or eliminated from any of the circuits shown.

Component mounting may be on a small single-side etched board—or copper clad is easily cut with a hobby knife where straight-line patterns are required. Vectorbord or thin plastic material may also be used. If plastic is used, merely heat a small piece of wire and melt the component mounting holes where needed. The probe tip may be a piece of stiff tinned wire or a pin-type connector. The use of the pin connector allows easy connection of clips, etc.

Caution: These felt pens are available with both metal and plastic caps. Should your pen have the metal cap, it (the cap) should be discarded. The tip may be isolated from the body by slipping a small piece of the inner insulation from a piece of RG-58/U cable over the tip and sliding it down into the probe body. The ground lead is a 6 to 8 in. piece of shield from RG-58/U cable. Be certain the ground lead is secured to the probe housing as well as the circuitry; then solder a clip to the free end.

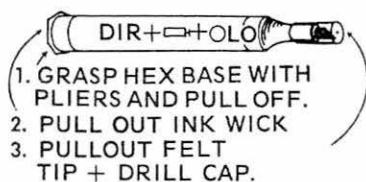


Fig. 1.

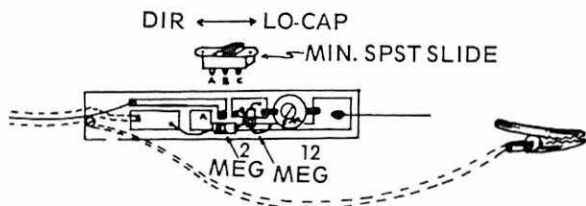


Fig. 2.

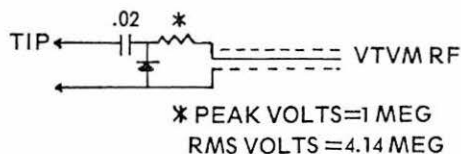


Fig. 3.

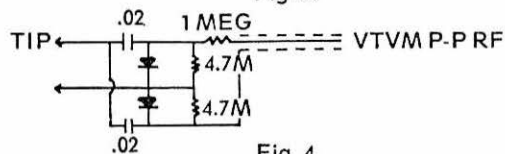
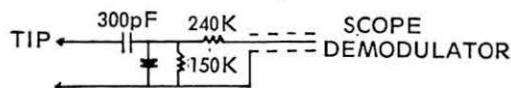


Fig. 4.



Fig. 5.



DIODES-1N55 OR SIMILAR FOR VOLTAGES UP TO 50V.

Fig. 6.

The circuits shown are designed for VTVM or VOM with an impedance of more than 10 megohms per volt. The scope probes are designed for scopes with a 1M input impedance.

In the following circuits, the dc blocking capacitors are 600V rated. The 1N55 diode has a PIV rating of 150V and will safely handle 50V of rf. Once the assembled circuit with connecting cable has been inserted into the probe body, push a small plastic cap, which has been drilled, over the cable, and onto the open end of the probe. Be sure the cable shield is grounded to the circuit ground as well as the probe body. A small amount of RTV rubber seal (made by GE) inside the plastic cap will act as a strain relief.

Crystal Tester

by Mike Kaufman

Here is an easy-to-build crystal tester that will tell you at a glance whether or not a crystal is capable of oscillation. Battery operated and inexpensive to construct, the tester will find use in weeding out those questionable pull-out crystals that have been accumulating in the shop for years.

To use the tester, simply insert the crystal to be tested into one of the crystal sockets and press the test switch. If the indicator lamp glows, the crystal is good. If the lamp does not glow, the crystal is bad...what could be simpler?

The tester checks for oscillations but does not check that the crystal is oscillating at its marked frequency. Crystals that fail the test inevitably are found to be fractured, or to have dirty contacts or broken leads. The tester has been used successfully to check "basic" crystals in the lower frequency ranges, and "overtone" crystals up to 90 MHz.

Figure 1 shows the schematic of the tester. The circuit portion at left forms an untuned Colpitts crystal oscillator circuit which is able to oscillate over a wide range of crystal frequencies. (Of course, the absence of tuned circuits to reject harmonics means the oscillator output will not be a pure sinusoidal pattern, but this is of no concern in the present application.)

With a good crystal in the circuit and the test switch closed, the circuit will oscillate and several volts peak-to-peak will be developed across the resistor in the output of the first stage. This peak-to-peak voltage produces a dc bias at the base of the output transistor and thus causes the indicator lamp to glow.

If the crystal under test is bad (i.e., fails to oscillate) no signal will pass through the coupling capacitor and no bias will be developed at the base of the output transistor. Thus, the indicator lamp remains off, indicating a bad crystal.

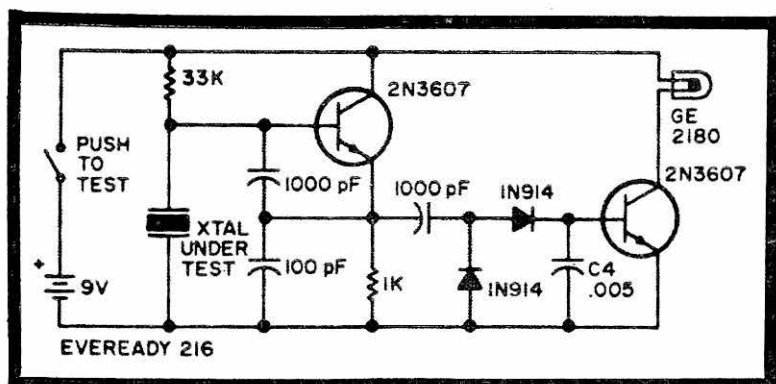


Fig. 1. Crystal tester schematic.

The photographs show the general appearance of the tester and the method of construction. Components are mounted on a $1\frac{3}{4} \times 3\frac{3}{4}$ in. piece of Vectorbord, which is mounted on $\frac{1}{8}$ in. standoffs from the bottom of a $4\frac{1}{4} \times 2\frac{1}{4} \times 1\frac{1}{2}$ in. minibox (BUD CU-3016A). Crystal sockets suitable for FT-243 and HC-6 / U were mounted on the lid of the minibox and wired in parallel to accommodate the most common types of crystal holders. A miniature SPST push switch and the indicator lamp were also mounted on the lid of the minibox.

Neither circuit layout nor component values are critical. The active components should be computer switching devices, although the output transistor can be any NPN capable of collector currents in the 50-100 mA range, as determined by the indicator lamp. All components shown in Fig. 1 could be purchased new for a total cost of under \$4, so the construction of this tester is not an expensive undertaking.

While I used a 9V transistor radio battery in the tester, any battery voltage from 6 to 15V could be used. The tester draws current only when the push switch is closed; thus, if tests are kept short, battery life will be quite long. The original crystal tester has been used to check perhaps 50 crystals over a two-year period and the original battery is still going strong!

Measuring the Frequency of Unmarked Crystals

by George R. Allen

Unmarked crystals are easy to obtain, but are of little value since the frequencies are unknown. By using a grid-dip oscillator or a surplus frequency meter, the frequencies of the unmarked crystals may be determined to an accuracy exceeding 1 percent depending on which instrument is used.

Measurement with Grid-Dip Oscillator

Figure 1 shows the setup for using a grid-dip oscillator to roughly determine the resonant frequency of an unmarked crystal. L1 is a four- or five-turn link, wound around the coil of the GDO. The coil may be soldered to a crystal socket or wrapped around the pins of the crystal being checked. To find the approximate frequency of the crystal, choose a low-band coil first, using the higher bands last. Avoid starting with high-band coils, as the measured frequency may be an overtone. Insert the coil in the GDO, place the GDO in the oscillator position, couple L1 to the GDO coil and vary the frequency of the GDO from low to high very slowly. At resonance, the GDO will dip very sharply. It is important to vary the frequency slowly or the sharp dip will be missed. The dial of the GDO will now read the approximate frequency of the crystal. If a dip is not obtained, it will be necessary to use the next highest coil for the GDO. When resonance is obtained, it will be possible, with careful tuning, to maintain a steady dip, at which point

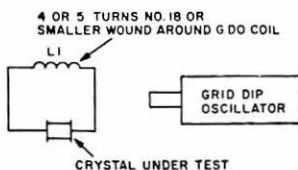


Fig. 1. Setup for rough frequency determination.

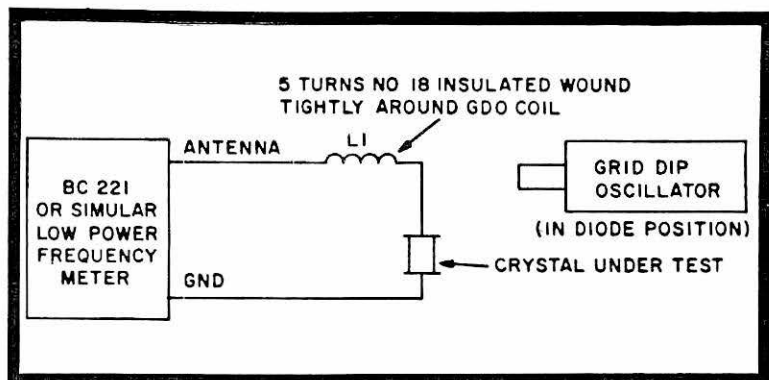


Fig. 2. Setup for accurate determination of crystal frequency.

the GDO will be locked to the frequency of the crystal. It is now possible to use a general-coverage receiver to pick up the oscillating crystal and thus determine the frequency of the crystal to an accuracy better than that of the GDO. If a general coverage receiver is not available, a surplus frequency meter such as the BC-211, may be used.

Figures 2 and 3 show two setups for using the BC-221 frequency meter to measure the frequency of unmarked crystals. Figure 2 uses the GDO as a detector, while Fig. 3 shows a more sensitive arrangement using a VTVM as a detector.

With the BC-221 or similar frequency meter, the crystal is connected across the output terminals, and the detector either coupled through a loop in the circuit or directly across the crystal. If a GDO is a part of the station equipment, the quickest way to determine the frequency is to first roughly find the frequency of the crystal using the GDO as previously described.

After the rough frequency has been determined, place the crystal in one of the circuits as shown in Fig. 2 or 3. If the GDO is used as the detector, do not alter the tuning when placing the GDO in the circuit. Starting at a frequency known to be above or below the rough crystal frequency, very slowly vary the frequency of the BC-211 toward the rough frequency, until an indication is observed either on the GDO in the diode position or on the VTVM. The indication in either case will be an upward deflection on the meter. In the case of the VTVM as a detector, there should be some residual reading on the meter which will increase when the crystal frequency is reached. In

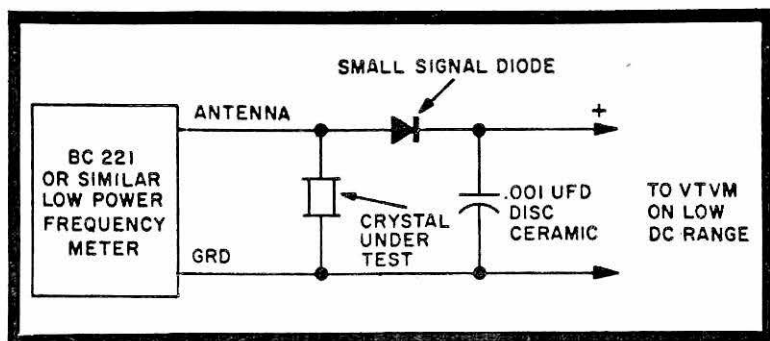


Fig. 3. Alternate setup for accurate determination of crystal frequency.

some cases, depending on the type of GDO and the frequency, the indication on the GDO may be barely discernible. In this case, it is recommended that the VTVM be used as the detector. If a GDO is not available, and it has been impossible to determine the rough frequency of the crystal, then the task is more time consuming. It will now be necessary to start the frequency meter at its lowest frequency and slowly vary the frequency upwards until an indication is noticed on the detector.

By using the techniques described, I have measured crystals in the range of 2 to 12 MHz with the results exceeding an accuracy of 1 percent. If it's necessary to determine the frequency of a crystal to an accuracy much better than this, then the crystal should be placed in the oscillator to be used, and the frequency checked by using more sophisticated methods. These techniques are presented because of their speed, simplicity, and reasonable accuracy.

Coil Q Tester

by Bud Votipka

How good are your coils? Q, the figure of coil merit can be easily measured with a simple instrument.

Until now very little has been mentioned in magazine articles regarding the Q meter and its application and construction. This one can be built for approximately \$20 (or for \$5 if your buddy has lots of parts).

The Q meter operates on the principle of resonance. To obtain this resonance, two conditions must be met: (1) there must be a circuit capable of resonance, (2) there must be a signal to which the circuit can resonate.

The block diagram (Fig. 1) shows the basic parts of the instrument. The oscillator provides the signal and calibration voltage. This calibration voltage is applied to the tuned circuit through a 100:1 voltage divider. This voltage (let's call it drive voltage) is amplified by the tuned circuit at resonance, detected, and measured on a voltmeter.

In operation, a small voltage (E_1) is introduced in series with a tuned circuit, the unknown coil, and C3. The circuit is then tuned to resonance and the voltage (E_2) developed across the tuned circuit is measured on the voltmeter. The measured voltage (E_2) is then compared to the driving voltage (E_1). The Q of the circuit is then the measured voltage divided by the drive voltage, or:

$$Q = E_2 / E_1$$

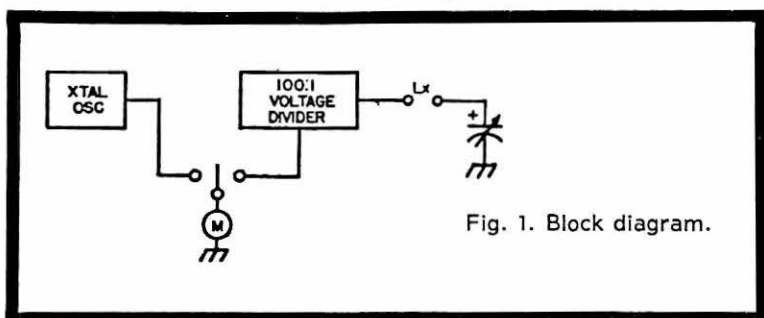


Fig. 1. Block diagram.

Thus, a driving voltage of 1V using a 100:1 divider for E_2 at resonance of 1V gives a Q of 100. Any losses in the resonant circuit will result in a lower Q reading. In general, the losses in the coil are much greater than the losses in the other circuit elements. Thus, the Q of the circuit is the Q of the coil for all practical purposes.

The battery powered Q-meter (shown in Fig. 2) uses only three transistors: one as crystal oscillator and calibration source, the other two as a high-impedance voltmeter. Use of a crystal-type oscillator provides a more stable and less complicated circuitry than a variable oscillator, although a tunable oscillator is used in the lab-type Q-meter.

Crystal switching can be used if necessary. The stability of the crystal oscillator also allows the calibrating voltage and the drive voltage to be used directly without the use of emitter followers to isolate the load from the oscillator. The current drain is only 1.5 mA, so battery life should be no problem.

Building the Q-meter is simple, although good rf construction should be followed (e.g., short signal leads and common rf ground).

The tuning capacitor must have very low-loss insulating material used in its construction. Ceramic, Rexlite, or Teflon

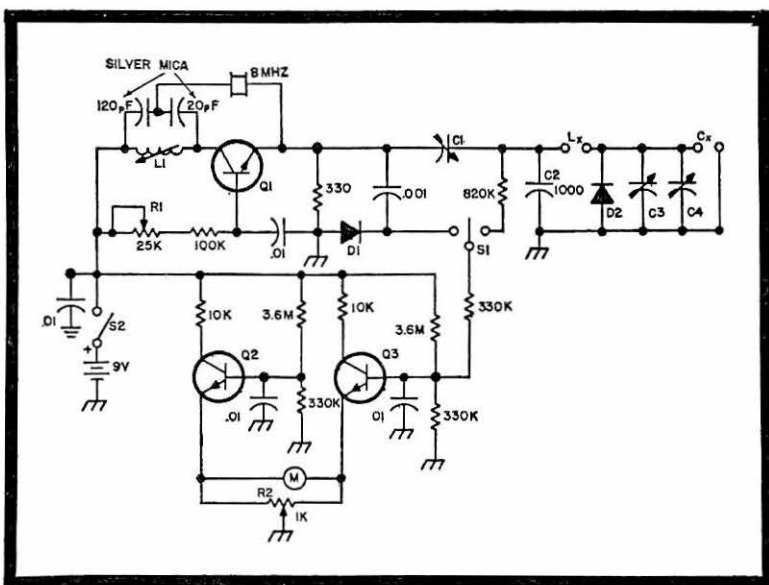


Fig. 2. Schematic diagram of the battery powered "Q-Meter."

insulation is preferred. The fiber board used in the ordinary broadcaster capacitor, while usable in a pi network (where the in-circuit Q is around 10-20) definitely has too much loss for this application. Many surplus capacitors with low-loss ceramic insulators are available and one with a vernier drive is to be preferred. The one used here is a J.W. Miller 2111 with the fiber insulators removed and 4 small ceramic standoffs (similar to Cambion 3848-2) added to support the stator.

Capacitor C4 is a surplus-type CT15 modified to two stators and one rotor plate. The meter is mounted into a tight-fitting hole in the front panel. A dab of rubber cement between a corner of the meter and the chassis provides the necessary security.

The terminal binding post should be mounted on a good insulator (such as Lucite) and mounted under a cutout at least $\frac{1}{4}$ in. larger than the post dimensions to reduce stray capacity. Also use heavy 14-gage bus wire or brass strap to keep the inductance down in leads connecting the binding post and tank capacitor together.

Diode D₂ is mounted directly in the L_x binding post to ground. Capacitor C1 is mounted on a small terminal strip near L_x binding post. The crystal oscillator and voltmeter circuitry are built on a piece of Vectorbord using flea clips and point-to-point wiring.

Now that we have the Q-meter built, let's calibrate it. Rotate Cal-Q switch to CAL. Turn R1 to turn meter on, adjust R2 to zero the meter. If meter cannot be zeroed, check wiring for errors. There should be no problem, as this is a very straightforward dc amplifier.

After zeroing meter, rotate Cal-Q to CAL position, adjust oscillator coil slug (L₁) for maximum on meter, then turn slug slightly into coil so oscillator starts in application of power every time. Adjust R1 (set level) control for 50 uA on meter. This reading of 50 uA is used as the reference set level on the meter for all future use of the instrument and may be marked on meter face.

Now for calibration of LC scales and Q-meter face. With a coil (tapped per Fig. 3) connected across the unknown L_x terminals switch to Q, zero meter, rotate C dial knob (C3) for peak on meter with vernier tuning (C4) set at mid-capacity. Using the A to D taps on the standard coil, connect resistors in parallel across the unknown (L_x) binding post, to complete calibration of meter face using Q values versus resistance in

TURNS	TAP	Q	C, pF	L, uH
7	A-B	135	256	1.57
13	A-C	210	106	3.8
18	A-D	235	69	7
23	A-E	260	50	8
6	B-C	120	310	1.28
11	B-D	180	134	3
16	B-E	215	69	7
10	C-E	170	151	2.62
11	F-E	195	120	3.35
16	F-D	230	77	5.2
21	F-C	280	55	7.4
27	F-B	275	39	10
34	A-F			

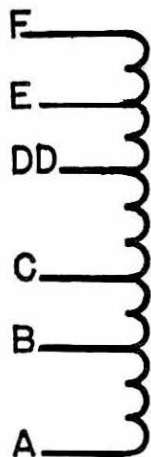


Fig. 3. Coil data.

Fig. 4. After calibration, appropriate marking may be made by transfer letters or pen and ink. The intermediate points may be marked by interpolation.

The standard coil has been measured on a Marconi 1245 Lab Q-meter and of 5 coils built and measured, the tolerance spread was less than 3 percent maximum between coils. With reasonable care in tapping the coil and calibration, you can have an instrument within 5 percent of lab equipment.

The true experimenter may not be satisfied with the fixed frequency used in this unit, so if you have a good rf signal generator, it can be pressed into service as a vfo for this unit by changing Q1 to a common-emitter amplifier as in Fig. 5.

A-D	Q = 235
= 165	
= 145	
= 140	
= 110	
= 104	
= 90	
= 85	
= 57	
= 39	
= 25	

R = 0
= 220k
= 150k
= 100k
= 68k
= 56k
= 47k
= 33k
= 22k
= 15k
= 10k

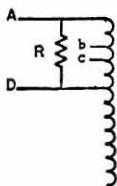
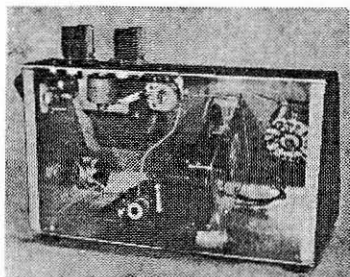
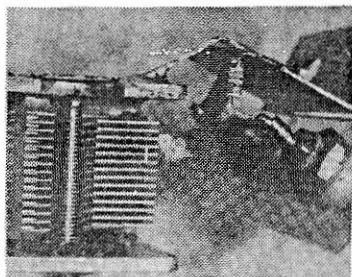


Fig. 4. Q values vs resistance.



Interior of the Q-meter.



Inside view of mounting of diode and straps connecting the binding posts to the capacitor.

When using the external signal source (vfo) this unit will work very satisfactorily up to 25.2 MHz, with a degrading of 15-20 percent for Q above 200, in the range of 15-50 there is no error measurable at this frequency. Standard frequencies for measuring Q are 25.25 MHz, 7.95 MHz, and 795 kHz. For inductance, use values of 0.1-1 uH, 1-10 uH, and 10-100 uH, respectively.

The following procedures may be used as a guide in operation of the Q-meter:

1. To measure the inductance of a coil:

Set Cal-Q switch to CAL.

Connect the coil to the L_x terminals.

Adjust R1 to Cal (50 uA).

Set the Cal-Q switch to Q.

Set tuning (C3) to maximum counterclockwise.

Adjust R2 for zero on meter.

Adjust tuning (C3) for maximum indication on meter.

Read the inductance on the L scale.

2. To measure the Q of the coil:

Set the Cal-Q switch to CAL.

Connect the coil to the L_x terminals.

Adjust R1 to Cal (50 uA).

Set the Cal-Q switch to Q.

Set tuning (C3) to maximum counterclockwise.

Adjust R2 for zero on meter.

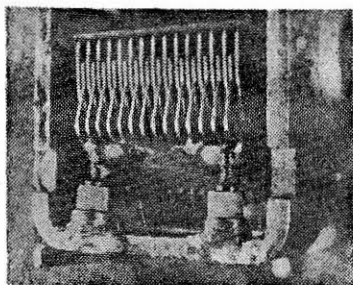
Adjust tuning (C3) for maximum indication on meter.

Read the Q of the coil on the meter.

3. To measure capacity by substitution:

Set the Cal-Q switch to CAL.

Connect a test coil across the L_x terminals.



Inside view of variable capacitor (C3) showing two ceramic standoffs for support of the stator.

Adjust R1 to Cal (50 uA).

Set the Cal-Q switch to Q.

Set tuning (C3) to maximum counterclockwise.

Adjust R2 for zero on meter.

Adjust tuning (C3) for maximum indication on meter.

Note the value on the C scale as C_a .

Connect the unknown capacitor across the C_x terminals.

Switch to CAL and check Cal level.

Switch to Q.

Adjust tuning (C3) for maximum indication on meter.

Note the value on C scale as C_b .

The unknown capacity added across the C_x terminals is found by subtracting the C_b value from the C_a value. $C_x = C_a - C_b$.

Now that you have the L, C, and Q of a coil, you may wonder what is its parallel resistance? Without going deep into theory, we may use the relationship:

$$\text{Parallel resistance } (R_p) = 2\pi f L Q$$

where L = measured value

Q = measured value

Therefore at 8 MHz,

$$2\pi f = 2 \times 3.1416 \times 86$$

$$= 50.04 \times 106$$

Let's keep this value of $2\pi f = 50.05 \times 106$ as a constant factor for further use. As an example, let's find the R_p at tap A-B in Fig. 3.

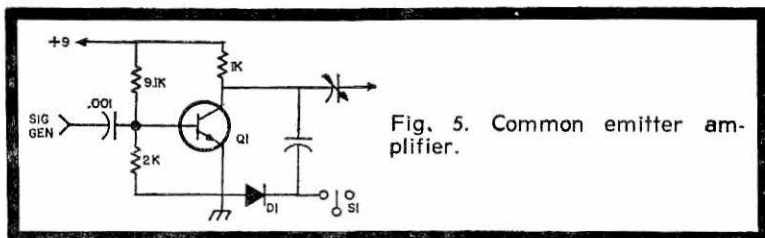


Fig. 5. Common emitter amplifier.

$$\begin{aligned}
 2\pi fLQ &= (50.04 \times 10^6) (7 \times 10^{-6}) (235) \\
 &= (50.04) (7) (235) \\
 &= 82,250 \text{ ohms or } 82.2\text{K}
 \end{aligned}$$

for tap A-C, $R_p = (50.04) (3.8) (210) = 39\text{K}$

and for tap B-D, $R_p = (50.04) (3) (180) = 12\text{K}$

The above examples stress the need for high quality components used in the Q-meter, as all losses are charged to the coil and would give much lower readings than expected. These examples are by no means all the Q-meter can do. This meter (with pencil, paper, and a little work) can be used in the initial design of transmitters, receivers, and converters, or just about anything using rf, coils, and capacitors.

Universal Dual-Frequency Crystal Calibrator

by John J. Schultz

Here is a simple and inexpensive crystal calibrator circuit using ICs which can be used as presented or expanded to build a "tailored" calibrator for any receiver.

It is often desirable to have a crystal calibrator with two or more output frequencies and with a rich harmonic content so that searching for markers on the higher frequency amateur bands, such as 10 and 15 meters, is made easier. Both of these goals are easily achieved by the use of digital integrated circuits. Furthermore, the whole calibrator unit is far simpler to construct and more economical than ever would be possible with either vacuum-tube circuitry or discrete solid-state circuitry.

The calibrator to be described, which provides markers at the fundamental crystal frequency used, is termed "universal" for several reasons. No tuned circuits are used and the unit can be used with almost any crystal from 100 kHz to about 10 MHz and still provide a fundamental and half-frequency output. The stages are really "building blocks" and the unit can be expanded in any manner desired to provide multiple frequency outputs or to use any division ratio that is an even multiple of two. Thus, depending upon the calibration markings on the frequency scale of a receiver or transceiver, one can build a calibrator that will suit these markings rather than accept the output of a standard calibrator circuit.

Circuit Description

Figure 1 shows a block diagram of the basic calibrator unit. Two Fairchild uL 914 units form the oscillator circuit. As can be traced by following the circuit diagram of Fig. 2 and the internal uL 914 circuit, the oscillator is actually a multi-vibrator which is controlled by the frequency of the

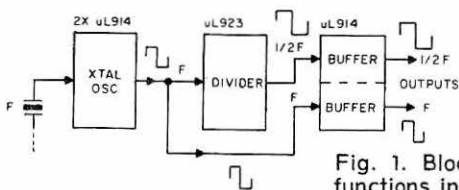


Fig. 1. Block diagram of stage functions in the calibrator.

crystal used. Circuit operation is very stable and the square-wave output not only has the desired richness in harmonics (remembering that a square wave is composed of a sine wave fundamental and an "infinite" number of harmonics of the fundamental), but is the required waveform to operate the divider circuit.

The divider circuit uses a single Fairchild uL 923. The IC contains some 12 transistors in an arrangement known as JK flip-flop. It probably would only cause confusion to present the internal circuit of the unit, especially since its operation can be understood easily (for this application) simply in terms of its terminal functions.

The unit can be regarded as a simple toggle switch that will only operate when it receives a positive going voltage. (Note that the voltage must be changing; a steady voltage does not affect it.) So, if a square wave is applied which starts out positive, it will trip the switch. The switch will not be tripped again until the next square wave cycle. And again the switch will not be tripped until another whole input cycle occurs. Thus, the switch changes position half as fast as the input, and the output frequency is half that of the input frequency and also a square wave.

The buffer stage is not absolutely necessary, but it does isolate the output from the divider stage and also insures a maximum voltage swing at the output. As shown in the insert diagram of Fig. 2 there are really two separate dual transistor stages in the uL 914, and each of them is used as a separate buffer section—one for the fundamental marker output and one for the half-frequency marker output.

One can include as many divide-by-two uL 923 stages between the oscillator and buffer as desired. Only the final divided output can be used or one can switch-select outputs at the input and output of each divider stage. Some of the

tradeoffs that might be involved in constructing a long string of dividers to obtain a given marker frequency are discussed later.

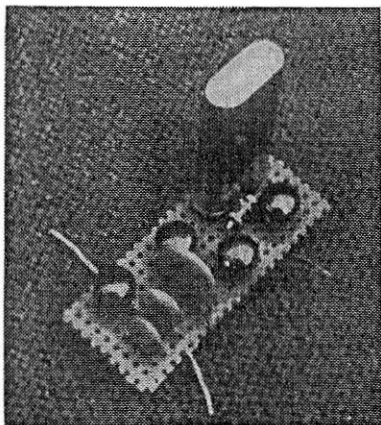
Figure 2 shows the wiring diagram of the dual frequency calibrator. There is little more to the unit than the interconnection of leads between the IC units.

The photograph shows how this circuit was assembled on a piece of perforated board. The leads of the ICs were simply soldered directly together, although the use of IC sockets is recommended if one is not adept at soldering connections quickly, since excessive heat can destroy the IC units. The circuit also easily lends itself to PC board construction.

The 1K resistor shown in series with the crystal may have to be varied in value somewhat to achieve immediate oscillation upon the application of power to the unit. A 5K potentiometer can initially be used in place of the resistor to determine the resistor value required and then a fixed value resistor substituted. An oscilloscope is useful but not absolutely necessary at this point to optimize the square wave output shape of the oscillator.

The oscillator will work with crystals up to about 10 MHz and a crystal switch can be used if desired to obtain a choice of fundamental frequencies. Each crystal should, however, be placed in series with an individual 1K resistor (nominal value).

The output is taken from each section of the uL 914 buffer unit through 100 pF coupling capacitors and may be connected to the antenna input circuit of a receiver through a selector switch. The output may also be connected to the secondary



Many construction possibilities can be devised. Here the calibrator is assembled on a 1-inch x 2½-inch perforated board. The placement of the ICs simply follows Fig. 2, with the two oscillator circuit uL 914s next to the crystal.

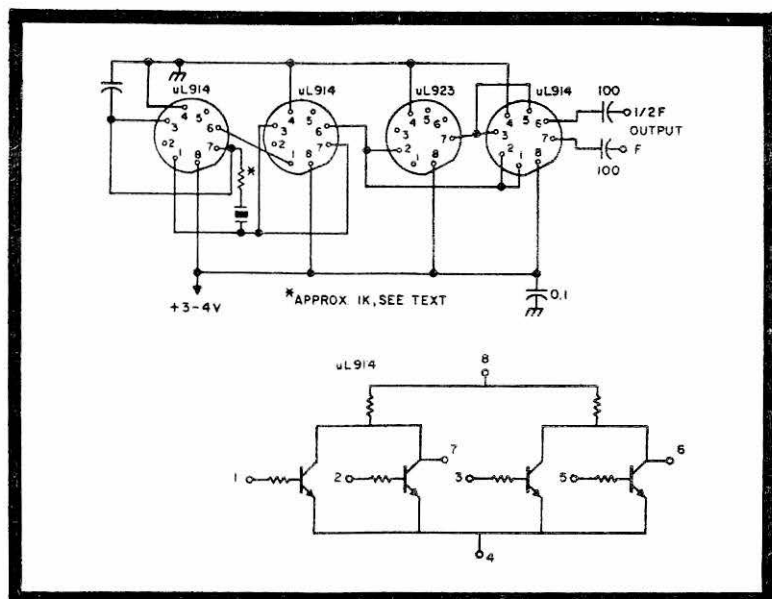


Fig. 2. Complete schematic of the dual frequency calibrator. Insert drawing shows internal circuit of the uL 914. Terminal numbers for the ICs are shown as they would be seen viewing the units from the underside.

side of the input circuit of a receiver; but then the coupling capacitors should be reduced to a few picofarads to prevent loading and detuning. One need use only as much capacitance as is necessary to obtain satisfactory signal output.

Note should be made of the fact that when using both sections of the uL 914 as buffers on different frequencies, some intercoupling does take place. The selected output will predominate, but the other output will also be heard. Normally, this condition has little practical drawback, but if it is desired to achieve maximum separation, only one section of a uL 914 unit should be used per uL 914 unit.

Normally, the slight adjustments necessary to choose the proper crystal circuit resistor and to couple the unit to a receiver are all that is necessary. No provision was made to "trim" the oscillator frequency for several reasons. When using low-frequency crystals (below about 500 kHz), the accuracy will be sufficient for most normal uses. Also, normally this accuracy will be within that to which it is possible to adjust the crystal frequency by the usual audio zero-beat method. When zero-beating a marker with WWV, for example,

the response of the audio system, headphones, etc., drops sharply below 50-100 Hz. So, there will be an uncertain area of about 100-200 cycles, anyway, using this method of adjustment where zero-beat seems to occur. However, in case it is desired to try for more exact frequency output, a 15 pF trimmer can be used either in parallel or in series with the crystal to alter its frequency.

The unit constructed used individual ICs which can now be obtained widely at moderate prices. If one builds a more elaborate unit the use of dual ICs might prove cost saving. Poly Paks, P.O. Box 942, So. Lynnfield, Massachusetts 01940, for instance, markets the 6M4 unit for \$1.49 which contains two complete uL 914 chips and the 10M4 for \$1.69 which contains two complete uL 923 chips.

Expanded Circuits

As was mentioned before, as many uL 923 divide-by-two units can be placed in series as desired. The output (terminal 7) of one uL 923 unit goes to the input (terminal 2) of the next uL 923 unit. Pin 4 of each unit is grounded and pin 8 goes to the supply voltage.

In building a calibrator for a specific usage it is worthwhile to explore the cost tradeoff between the uL 923 units and the cost or availability of the crystal. Suppose, for instance,

DIVISION RATIO	uL 923 UNITS	XTAL FREQ (kHz)
2	1	40
4	2	80
8	3	160
16	4	320
32	5	640
64	6	1280

Fig. 3. Combinations possible to build a calibrator producing 20 kHz markers.

you desired to build a calibrator to provide markers every 20 kHz to correspond to the frequency markings on a dial scale. Figure 3 shows some of the combinations of crystal frequency and the number of uL 923 units that could be used. Normally, 40 or 80 kHz crystals would not be feasible, but 160 kHz crystals can be purchased for about \$4. Also, many surplus low-frequency crystals are available at low prices which can be used. Many an odd-ball crystal frequency becomes very useful when one finds the right division ratio to use with it.

Summary

I have tried to present a simple IC calibrator scheme which one can expand, as desired, to cover almost any marker-frequency need. Simple circuits have been used, although only slightly more complicated ones are available to allow frequency division by any number—not just even multiples of two. But they are not suggested as a first-time project, and it is desirable to have test equipment available to check their operation. The divide-by-two circuits are essentially foolproof, unless one makes a wiring error.

Power for the calibrator can be obtained from a fairly well filtered source in a receiver or from two 1.5 dry cells in series. A simple zener regulator circuit is advisable if the operating power is obtained from the drop across a cathode resistor or from a rectifier across the filament line in a tube-type receiver.

The Meter Evaluator

by Marovich

To the serious experimenter or technician, one of the most useful electronic components is undoubtedly the ordinary meter, and in an effort to obtain more precise measurements, an increasing number of us are turning to the moderately priced surplus and imported units now appearing on the market. As any experimenter knows, however, with such a wide variety of types and styles available, it is virtually assured that no matter what the intended application, the available unit will always have the wrong range. To use such a meter, then, it is usually necessary to construct a shunt or a multiplier; and this, in turn, requires a knowledge of the meter's internal resistance. Since this parameter is rarely specified on the meter itself, it further becomes necessary that the experimenter be able to measure it as accurately as possible. In this respect, it is sad to say, conventional techniques leave a great deal to be desired.

It often comes as a surprise, particularly to those who wind their own shunts and who trust their meters, to learn that by using one conventional technique, it is entirely possible for readings to be off by as much as 50 percent—and sometimes even more! Obviously, the accuracy of the method by which internal resistance is measured must be carefully considered, since the usefulness of the meter depends upon it. The purpose of this article is to examine the error incurred by the standard technique for measuring meter resistance, and to suggest a method which will overcome its limitations.

Measuring Meter Resistance (The Old Way)

The standard method of measuring internal resistance, covered in virtually every text on dc measurement, is the

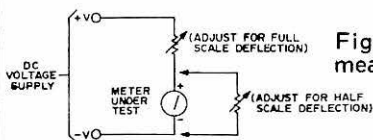


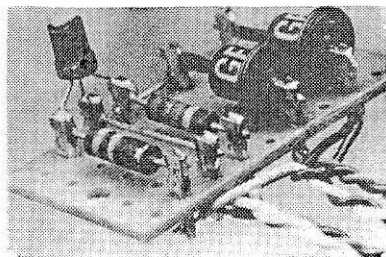
Fig. 1. Standard circuit for measuring meter resistance.

familiar two-resistor technique of Fig. 1. The explanation of how it works is fairly typical: The meter to be measured is connected in series with a stable dc voltage and a variable resistor, adjusted to produce full-scale deflection. A second resistor is then shunted across the meter and adjusted to produce a deflection of half-scale. At this point, it is claimed, the meter resistance is exactly equal to the shunt resistance, so that by disconnecting and measuring the shunt resistance one can determine the resistance of the meter. Unfortunately, that's not always the way it works out. The method is very widely used; it's cheap, simple, fast, and uses readily available junkbox parts. But it can also lead to considerable error; to see why, let's examine the operation of the circuit a little more closely.

The problem may be put in perspective by considering the circuit as redrawn in Fig. 2. In A, with R_{SH} disconnected and R_S again adjusted for full-scale deflection, a total current I_{FS} flows through the meter, and adjusted to produce half-scale deflection (sketch B), the total current divides between the two branches. If the total current is I_{FS} , then

$$I_{SH} = I_{FS} = \frac{1}{2} I_{FS} = \frac{1}{2} I_{FS}$$

and therefore the currents are equal. Since the voltages across the meter and shunt resistances are also equal (they're



connected in parallel, remember) it is obvious that their resistances should be equal. This situation is illustrated in sketch B of Fig. 2.

Is this what actually happens, however? No, it's not; let's look at the circuit again: The total current flow, we said, was I_{FS} , and that was certainly true before we connected R_{SH} . But how do we know that it is true afterward? The answer: we don't—and that's precisely the catch: the addition of R_{SH} in fact changes the total current because it changes the total circuit resistance. The shunt current still represents the difference between the meter current (still $\frac{1}{2}I_{FS}$) and the total current, but if the total current no longer remains equal to I_{FS} , and changes to some new value, say $I_{FS'}$, then the shunt current will be given by

$$I_{SH} = I_{FS'} - \frac{1}{2}I_{FS'}$$

which is not necessarily equal to $\frac{1}{2}I_{FS}$ (sketch C). In other words, when R_{SH} is connected and adjusted to produce a half-scale deflection, the currents I_M and I_{SH} are not necessarily equal, so that the meter and shunt resistances are not necessarily the same.

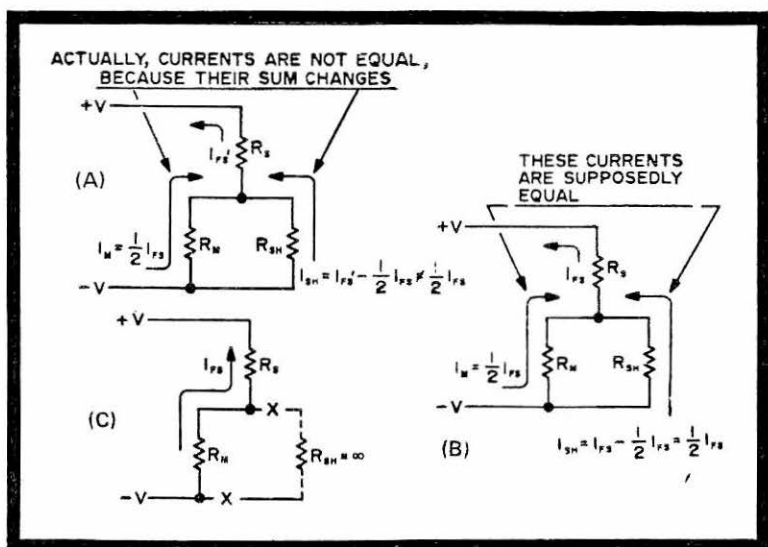
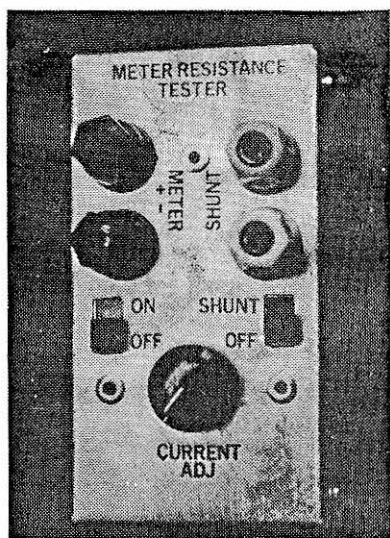


Fig. 2. The two-resistor technique. (A) R_{SH} disconnected and R_S adjusted for full-scale deflection. (B) What supposedly happens when R_{SH} is reconnected. (C) What actually happens! Note that I_M and I_{SH} are not equal if I_{FS} changes.



Front view of meter evaluator.
(Photo by Dale J. Ritter.)

What Now, Boss?

After having uncovered the basic cause of error in the two-resistor measurement technique, our problem is how to get rid of it. The inaccuracy, as we have seen, is basically due to the fact that the total circuit current—the sum of the meter and shunt currents—changes with the addition of the shunt. Seen from this perspective, a solution is obvious: simply feed both meter and shunt from a constant-current source, as shown in Fig. 3. This situation, in fact, is precisely what one obtains by greatly increasing the value of R_S , as suggested earlier. One problem with that approach, already pointed out, is that it's difficult to know just how much to increase it without knowing the meter resistance itself. A second problem is that in order to maintain a constant current, any increase in R_S necessitates a corresponding increase in the supply voltage. A

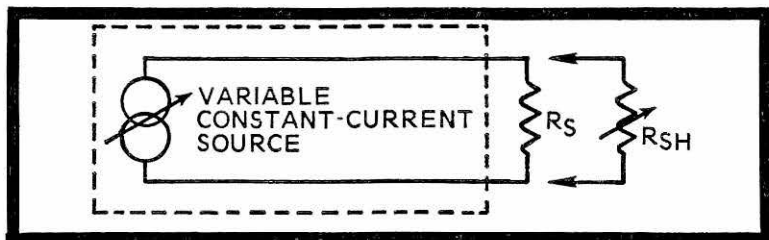


Fig. 3. A constant-current source is used to measure meter resistance.

variable high-voltage supply designed to deal with these difficulties is certainly not impossible to build, but it is really a rather cumbersome way to handle the matter in view of the fact that a much more elegant solution is available.

...Finally!

Since all we need to measure internal resistance with accuracy is a simple "black box" constant-current source, the contents of the "box" is immaterial, and any old circuit will do. One simple but effective approach is the circuit of Fig. 4, a modification of the one-transistor source commonly used in linear ICs.

Diodes D1 and D2 in the circuit act as voltage regulators, their intrinsic standoff potential being used to supply a stable voltage to the base of transistor Q1. Q1's beta should be as high as possible so that fluctuations in base current, due to variations in collector load resistance, do not significantly affect the base voltage. A GE 2N3390 or 2N3391 was selected as having the highest beta of any small-signal transistor known to this author (400 and 250, minimum, respectively), and their prices (90 cents and 61 cents) are not unreasonable either. To further insure the stability of the base voltage, R1 should be chosen so that the current through D1 and D2 is large enough to swamp out any fluctuations in base current. If the bias current is small, the collector and emitter currents will be

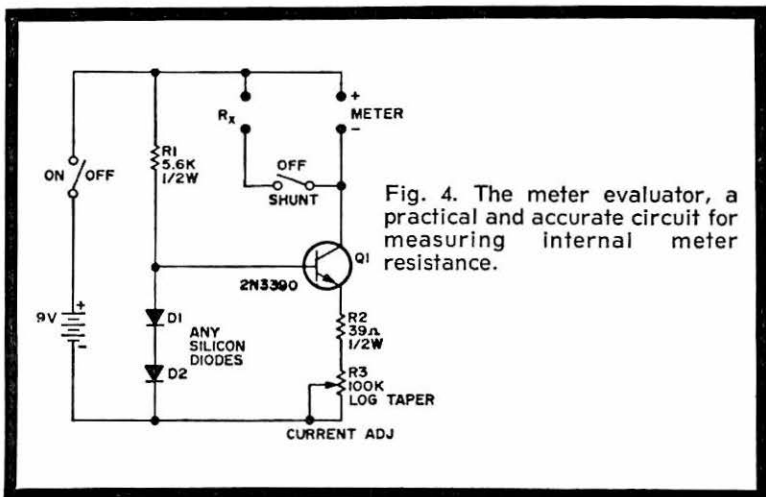
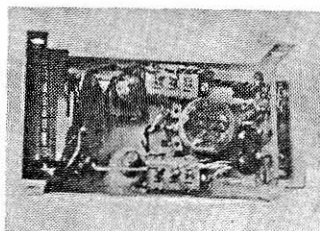


Fig. 4. The meter evaluator, a practical and accurate circuit for measuring internal meter resistance.



Interior view of meter evaluator.
(Photo by Dale J. Ritter.)

approximately equal, and if D1, D2, and Q1 are silicon units, both will be given by

$$I_C \approx I_E \approx \frac{.65}{R_E}$$

where R_E , the emitter resistance, is the sum of resistors R2 and R3. In my own prototype, R_E is adjustable from 39 ohms to 100K, which produces a current range of about 8 μ A to 13 mA—sufficient to measure most dc meter movements. The small parts are mounted on a $1\frac{1}{4} \times \frac{3}{4}$ in. rectangle of Vectorbord, and the entire unit is housed in a $4\frac{1}{4} \times 2\frac{1}{4} \times 1\frac{1}{2}$ in. aluminum minibox (Bud CU 3016A). The arrangement is convenient and compact, but otherwise the wiring is not critical.

To use the meter evaluator, connect the meter and shunt to the appropriate binding posts, then turn on the current and turn off the shunt switch. Rotate CURRENT ADJ until the meter reads full-scale. Flip the shunt switch to SHUNT and adjust the shunt resistor until the meter reads half-scale. The shunt resistance is then really equal to the meter resistance, and may be disconnected for measurement.

The File Box Resistance Decade

by Sam Milbourne

Have you been interested in finding a compact, economical way to package many small test equipment and transistor circuits?

If so, your search is ended. For less than one dollar, and obtainable in most five-and-dime stores, you can get a small metal file card box. One manufacturer is Ohio Art Company, Bryan OH 43506. The box has a top which swings open and shut, and it is usually painted green or gray. The metal used in making the box is about .03 in. thick; so when the panel is installed, the resulting unit is quite sturdy.

The Standard File Box

After some study, a standardized unit package was developed. This was a 4 x 6 x 4.5 in. file box. (The smaller 3 x 5 in. card box was rejected because for a very small additional cost the larger box had more panel space and larger volume.) The second step was to standardize on $\frac{1}{2}$ x $\frac{1}{2}$ x 1/16 in. aluminum angle for the panel brackets. These are Reynolds 2406 at about \$1.50 for a 6 ft length. Two $3\frac{3}{8}$ in. brackets would then cost you only 17 cents. Next, you will need aluminum panels. Use 0.030 in. semisoft aluminum sheet for easy drilling or punching. The actual size will depend on the inside dimensions of the file box used. If you can't get the panels sheared to size, they can be cut to size with large tin snips. Flatten these after cutting by placing between two pieces of wood and squeezing them flat in a vise.

Finally, four rubber mounts should be mounted on the bottom of the box, using the machine screws and nuts provided. Mounting holes should be positioned $\frac{3}{8}$ in. in from all sides. This will allow a space 3 x 5 in., within which a schematic can be mounted using a 3 x 5 file card. The finished schematic,

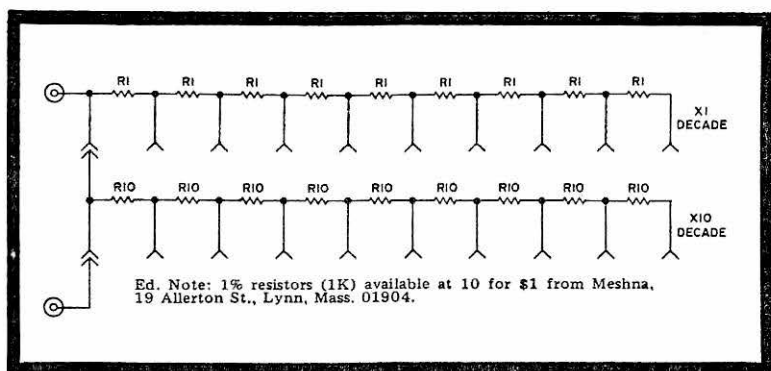


Fig. 1. Basic decade comprised of series resistors.

drawn in black ink, should then be covered with pressure-sensitive transparent film such as acetate or Mylar. This is usually available in office supply stores in sheet form. This card schematic can be attached to the bottom of the box with tape having adhesive on both sides.

Preparing the Panel

The blank panel should be prepared for layout by pasting to it a 4 x 6 blank card. The layout can then be made on the card, the panel drilled or punched out, and the card removed by soaking for a minute in hot water. The panel should then be cleaned thoroughly on both sides by using steel wool. A coat of zinc chromate should also be sprayed on both sides. Better yet, spray two light coats and steel wool between coats.

Clean with alcohol to remove any steel particles or dirt, and finish with two light coats of your favorite color lacquer.

I make titles in embossed tape, but dry transfer letters would work fine, I'm sure. Just remember to plastic-spray over transferred letters to prevent their eventual peeling.

Drilling Side Holes in Box

If you want to minimize the likelihood of damaging the box, you can make a wooden shell which will just fit inside the box so that the drilled hole will not break through the metal and unduly bend it.

First, drill the bottom holes using a No. 25 drill. Install the rubber feet using the 6-32 screws and nuts.

Next, drill the two holes in each end of the box to fasten the brackets. Position each set of holes $2\frac{1}{2}$ in. from the box bottom and 2 in. apart front to back, with the one hole positioned an inch from the box front.

Drilling brackets

Draw a horizontal pencil line on one side of each bracket, about $\frac{1}{4}$ in. from the bend in the bracket. Place each bracket inside the box and against the side of the box so that the line shows up through the two side holes. Pencil little circles using the holes as templates. Drill these four holes using a No. 35 drill. Slowly tap them with a 6-32 tap. Attach to box using 6-32 x $\frac{1}{4}$ in. machine screws.

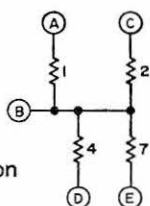
The panel (along with the other holes) will have two mounting holes on each side. They should be positioned $\frac{1}{4}$ in. in from each side of the panel, and 3 in. apart with front hole about $\frac{1}{2}$ in. from the box front. Place panel on brackets in box and spot bracket holes. Remove panel and drill holes and tap with 6-32 tap. Eventually, attach panel to box with 6-32 x $\frac{1}{4}$ in. machine screws.

Finishing the Box

The schematic and the operating instructions should now be attached under the box and inside the lid. The box should be identified on the outside front with the name of the test equipment it houses.

Figure 1 shows a basic series resistance decade. It is made up of nine identical values of resistance, each of which can be calibrated to a single high-accuracy resistance. It is easy to build, as all the resistors can be soldered directly to the

Fig. 2. The basic H configuration decade uses but four resistors.



R	FROM	TO
1	A	B
2	B	C
3	A	C
4	B	D
5	A	D
6	C	D
7	B	E
8	A	E
9	C	E

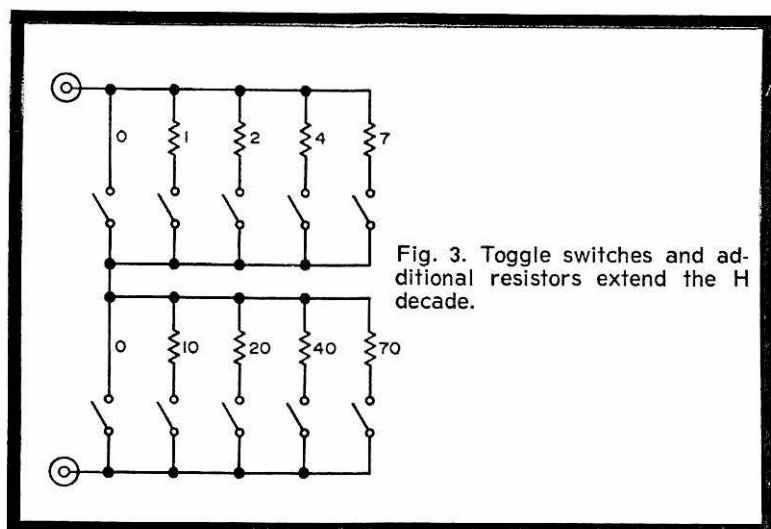


Fig. 3. Toggle switches and additional resistors extend the H decade.

rotary switch. However, since it does require a greater quantity of resistors throughout, it could double the cost.

Another type of resistance decade is the H configuration of Fig. 2. This uses only four resistors mounted on a small sub-panel. Note that the R1, R2, R4, and R7 values are used individually, but the other values are combinations of two resistor values. The connections are marked A to E; wires run between these points and the switching shown in Figs. 3 and 4. Figure 3 shows a dual decade resistance which uses ordinary toggle switches.

You will note that we have not talked about what the specific resistance values should be and what wattage resistors should be used. If you use composition resistors, it is suggested that 2W types be used. As far as the resistance values are concerned, they will depend upon the total resistance required of the decade. For instance, a 100K decade would be composed of a 10K, 20K, 40K, and 70K resistors.

It is suggested that you make up your first dual decade file box with 10K and 100K decades. Then build another with 100 ohm and 1K decades. This should cover the largest part of the resistance requirements. Other values, of course, can be used, but watch the added circuit resistance with low decade resistances.

The second switching method for the H configuration is the rotary switch shown in Fig. 4. A panel layout is shown in

Fig. 5. The panel markings shown for the various switch positions on the panel can be accomplished with metal escutcheons, or with dry transfers such as obtained with Datamark.

Accuracy

It is self-evident that resistors should be as precise as your pocketbook can afford. Why not start out with 5 percent carbon-film resistors; and when you run across more accurate values, just substitute them. One way to get the accuracy better, and by as much as an order of magnitude, is to use paired resistors of twice the value, and in parallel.

If you can beg or borrow the use of a good resistance bridge, you can calibrate the resistors quite accurately by taking two resistors in parallel. By selectively picking the resistors, you can come out with rather good accuracy. First, calibrate each resistor on the bridge, separating them into two piles: those plus and those minus the resistance value which is just twice the desired value. Then set the bridge to the final desired value and match plus and minus values until you get two that hit the correct value.

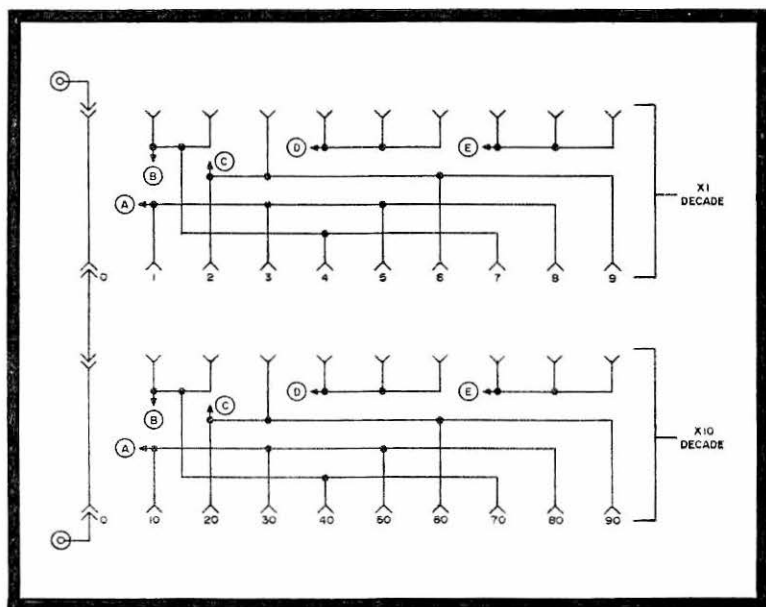


Fig. 4. Rotary switch connections for a dual decade.

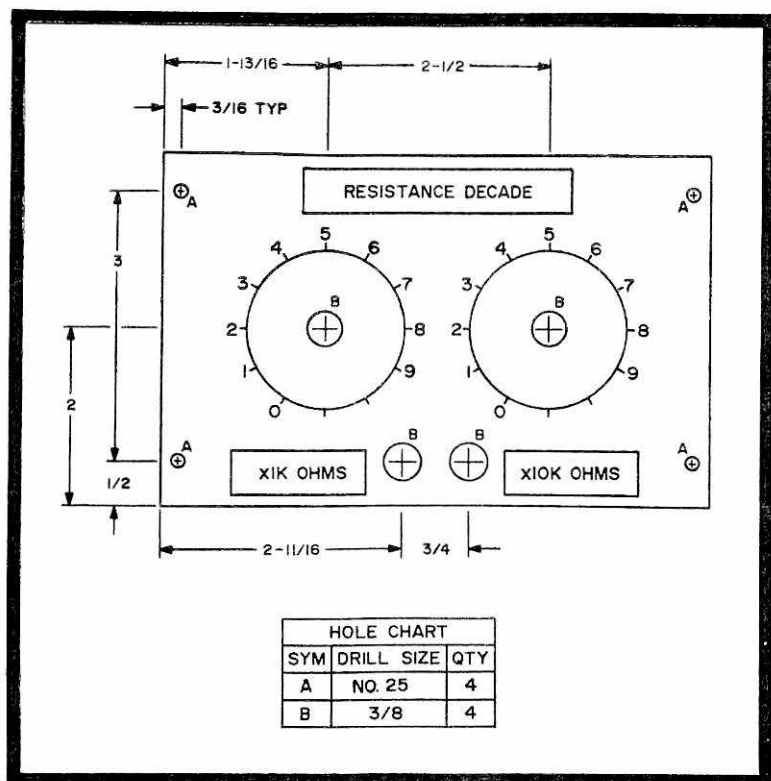


Fig. 5. Panel layout for the file box unit.

Just one caution: When you solder carbon resistors, treat them as you would a transistor. They can permanently change value due to too high applied heat. Use a pair of pliers as a heatsink between the resistor and the hot soldered joint.

When you have installed the panel in the specially worked file box, attached the schematic to the bottom and any information, such as calibration dates and accuracies, you will have a compact, useful test instrument that can help you a great deal in your building.

File Box Parts List

- (1) file box
- (2) pieces of $\frac{1}{2}$ in. aluminum bracket (4 in. lengths)
- (4) rubber feet with 6-32 mounting screws and nuts
- (1) panel, aluminum ($6\frac{1}{8}$ x $3\frac{15}{16}$ x .030 in.)

FM-AM Transmitter-Receiver Aligner

by Ed Goldsby

Many articles and ideas have been published in recent months which have been slanted toward the VHF amateur or commercial servicer. Most of them have been directed to the attention of the receiver. Little mention has been made of the transmitter.

I have been using receiver peaking and aligning generators for several years now, and since I am in the FM communications business as a profession, I have often wished that I had a small transistorized instrument that would take care of transmitter frequency and loading adjustments along with the receiver peaking.

The gadget I have conceived cannot be construed to be a precision test instrument; however, it does fulfill most of the requirements of the average VHF FM service specialist.

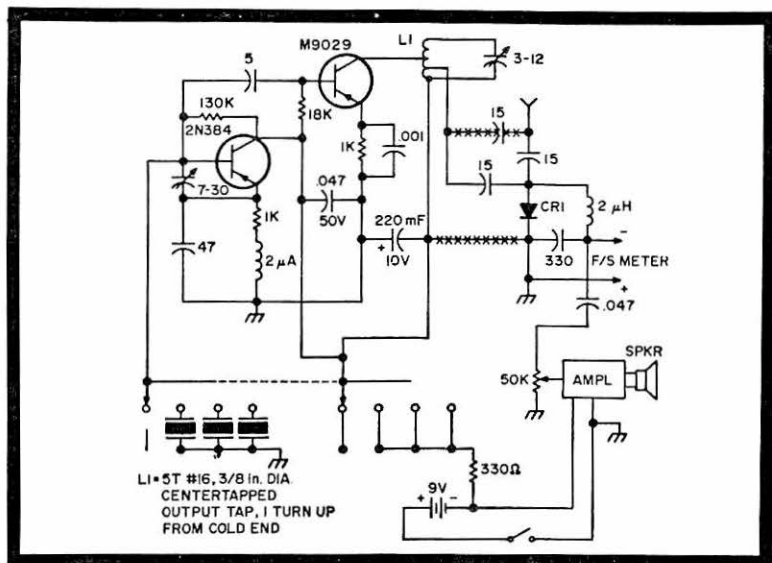
Basically, it starts off with the usual peaking generator, (a crystal oscillator and multiplier) followed by a diode mixer-detector and an audio amplifier with enough power to drive a small speaker.

The peaking generator, while generating a small signal for receiver alignment, also provides enough signal to the diode mixer to heterodyne with a signal from the transmitter which, when amplified in the audio section, may be used to align the transmitter to the receiver frequency—or any other preset crystal frequency. Simply tune the transmitter oscillator for zero beat in the speaker.

The circuitry also provides for connection of a relative field strength meter.

I chose to use PNP transistors because I had a 5-pound box of them. In the oscillator, I used a 2N384 and it took off strongly as soon as I applied battery voltage to it.

I tried several unmarked transistors in the multiplier and some of them worked pretty well, but the one I wound up using



was a Motorola M9029. Upon checking it out, I found that it is commonly used as an rf amplifier in some VHF receivers. I could find no equivalent 2N number for it.

For the multiplier coil, I used 5 turns of 16 AWG centertapped for the collector and an output tap one turn up from the cold end.

The diode mixer-detector was arrived at by "cut and try" also. I still don't know what the number is because there were no markings on it—not even the usual color bands. However, it works well at VHF frequencies and delivers enough output current to drive my field-strength meter to the pin (500 uA) at some distance from the transmitter.

For the audio section, I used one of those little Japanese 1W units I got from Allied Radio for \$4.95, but I could have used the audio portion of one of those little pocket receivers.

An Integrated-Circuit Electronic Counter

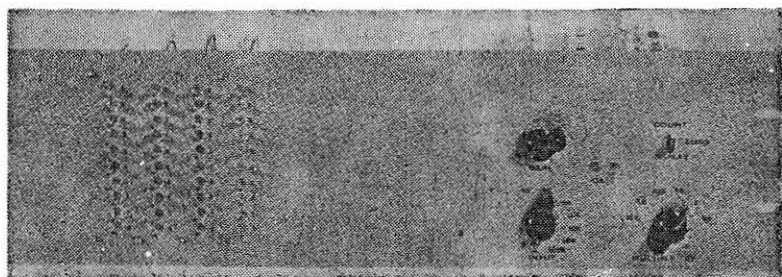
by George Jones

A digital frequency counter is a useful, though not common, piece of equipment to build on a "from scratch" basis. The continuing reduction in the prices of plastic encapsulated integrated circuits prompted my research to see if a good unit could be built easily with transistors and integrated circuits. The result is a counter which will go up to 10 MHz and has every feature a man could want, including direct decimal readout and completely automatic operation. With adequate prescaling, the counter will be usable on virtually any desirable frequency.

Principles of Operation

This counter displays the frequency in decimal numbers so that the operator doesn't have to convert from binary to decimal. On the 1 Hz multiplier range, the cycles of the input of the count can be watched on the neon lamps. The final count is then displayed for one second. The count period can be extended to any multiple of one second if greater than 1 Hz accuracy is needed and, likewise, the display can be held for as long as desired. At the end of the display period, the counters are reset to zero and the process starts over again.

On the 10 Hz multiplier range the same process is repeated 5 times a second; on the 100 Hz range, 50 times a second, etc.



Front view of the integrated-circuit frequency counter. The neon counting decades are on the left, count controls are on the right.

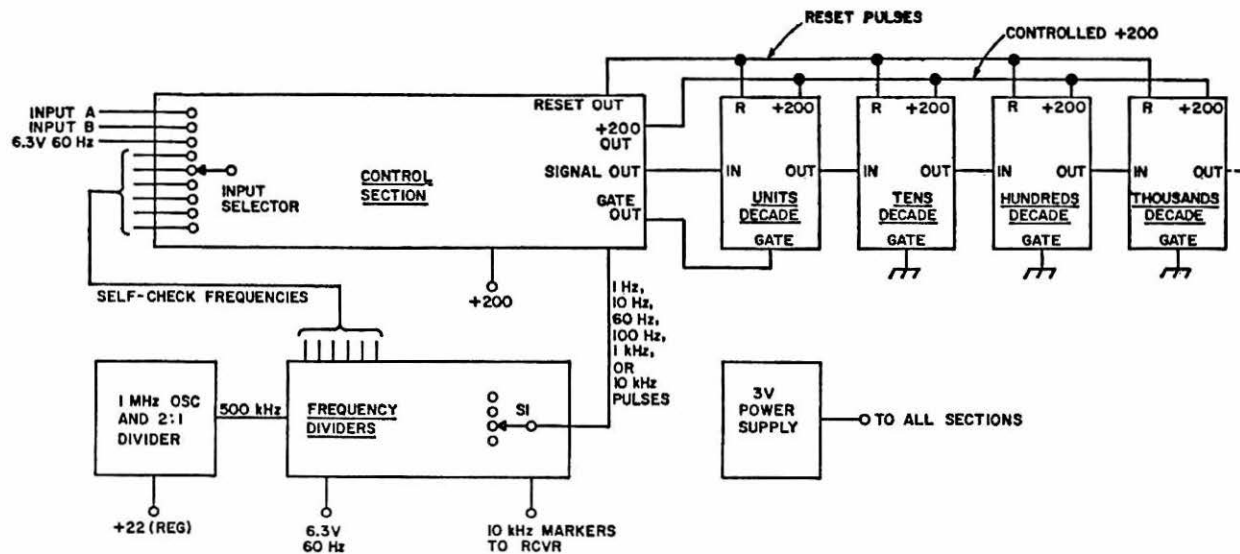


Fig. 1. Block diagram of the complete integrated circuit frequency counter. Any number of decades may be used, but for proper display, the units decade should be to the right, the tens decade to its left, etc.

To avoid confusion on the 10 Hz and higher ranges, the neon lamps are not lighted during the counting period and are, therefore, seen only displaying the final count. On the 10 Hz range, the display blinks 5 times a second, but on the 100 Hz and higher ranges, it appears continuous and appears to change immediately if the input frequency changes. Therefore, it combines the convenience of an analog display with the accuracy of a digital display. The last digit in this case usually vacillates between two adjacent numbers because the 1 Hz per gating period error inherent in a digital count.

The counter consists of three main sections. First, a frequency divider divides the signal from a 1 MHz standard down to 10 kHz, 1000 Hz, 100 Hz, 10 Hz, or 1 Hz, as required. A time base derived from the 60 Hz line could have been used but this would have limited the accuracy to 0.1 percent and would only have permitted the 10 Hz and 1 Hz ranges. This section also applies 10 kHz markers to the remainder of the frequency measuring setup. The 10 kHz pulses are rectangular in shape and have strong harmonics above 30 MHz. Therefore, they might as well be used as markers.

Second, a control section takes the desired time-base frequency and turns on the "units" counter for the correct length of time. It also shapes the input signal, so that the units counter will accept it, turns on the high-voltage supply for the neon lights during the display period, and supplies a reset pulse to all counting decades at the end of the display period.

Third, the counter proper consists of as many counting decades as the builder desires, one for each digit to be displayed. The units decade is gated by the control section and only counts pulses when the control section wants it to. For each 10 pulses the **units** decade is allowed to count, one is passed on to the **tens** decade, likewise for each 10 pulses the **tens** decades receives it passes one on to the **hundreds** decade, etc.

The decade counters, after the units decade, are not gated since they only receive pulses if the units decade is supplying them. Although the decades count by binary flip-flops, suitable feedback circuits make them count in decimal instead of binary. A decoding network and 10 transistors allow one of 10 neon lamps on the decade to be turned on to display one digit of the measured frequency. Each decade can also be reset to zero by a reset pulse from the control section.

fifth input pulse to produce an output pulse.

The 5:1 divider can be best understood from the diagram and waveforms of Fig. 4. Without an input signal, the inverter input is held high by the connection to positive voltage thru R1. The inverter output is, therefore, low so that low appears on the set input of the flip-flop. If the 0 output of the flip-flop is initially high, the first negative-going transition on the toggle input will make it go low. This change will be passed on to the inverter through C1 and this will make the set input go high so that the 0 output cannot go low again when more input pulses come in. C1 will charge through R1 and, after a delay, the inverter output and the set input will go low again so that the flip-flop can respond to an input pulse. If the divider is adjusted correctly, it will pass every fifth input pulse.

Other division ratios can be obtained, and maybe it would work with a division ratio of 10, but the ratio of 5 makes the division ratio very stable. In fact, it does not go out of adjustment for a change in the supply voltage from 3.0 to 4.0V.

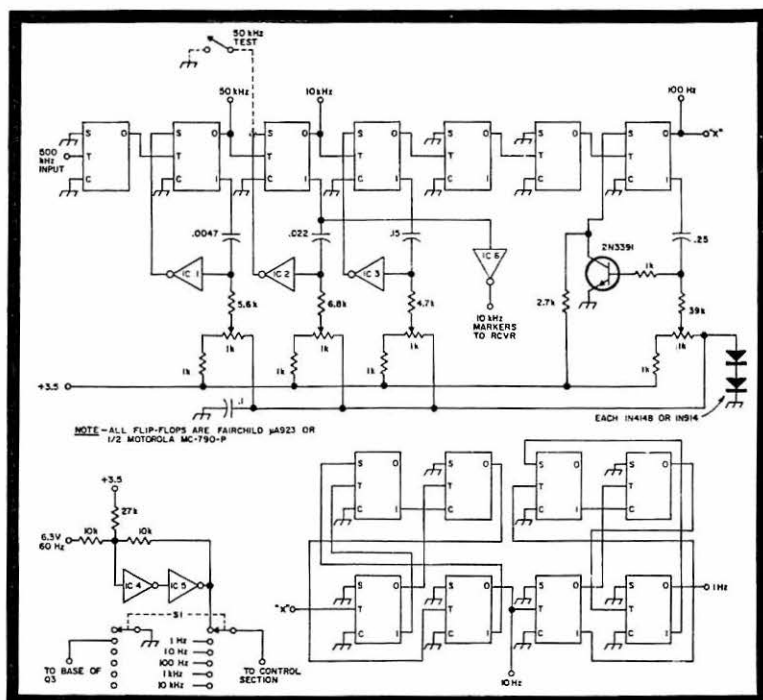


Fig. 3. The frequency dividers used in the IC counter. Integrated circuits IC1 through IC5 are one-half of Fairchild 914's or part of Motorola MC-789-P or MC-724-P; IC6 is a Fairchild 900 or one-half a Motorola MC-799-P.

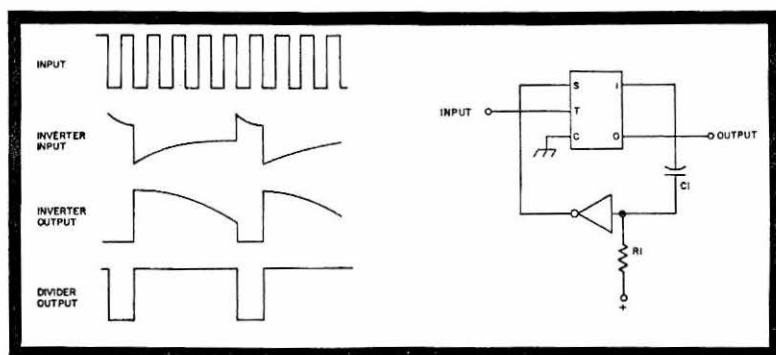


Fig. 4. The basic 5:1 frequency divide using a J-K flip-flop, an RC circuit and an inverter, along with the waveforms.

The first three 5:1 dividers are identical except for time-constant values. The output of the 10 kHz divider is fed through a buffer to the station receiver and frequency measuring equipment. The markers are very strong through 30 MHz. If the receiver calibration cannot be trusted to 10 kHz, the 50 kHz test button, shown in dotted lines in Fig. 2, can be provided. Pushing this button makes the 50 kHz markers louder and the other 10 kHz markers turn into 25 kHz markers. The counter proper does not read correctly while this is being done, but this doesn't matter since identifying the markers is done separately from making the final count.

The divider from 500 Hz to 100 Hz uses a discrete high-beta transistor instead of a gate, so that a higher resistor value and, therefore, a smaller capacitor value can be used. The dividers to 10 Hz and 1 Hz use decade dividers, with four J-K flip-flops in order to avoid even larger capacitors. This type of circuit could have been used for all the dividers and would have eliminated the need to adjust the dividers. The circuit of these dividers will be described in the section on the counting decades which use the same circuit.

The switch, S1, selects the divider frequency whose period is equal to the desired gate time and is calibrated in factors, by which the counter reading must be multiplied, rather than in gate time. The x60 position takes the time base from the ac line instead of the dividers, and is useful in adjusting the dividers. For example, to adjust the divider whose output frequency is 50 kHz the input switch is set to 50 kHz, the multiplier switch to 60, and the counter should read 833. This reading will jump around a bit, due to instability in the ac line frequency, but the

reading for the 10 kHz divider will only vacillate between 166 and 167.

Control Section

The input selector switch, S2 (Fig. 5), selects the desired input which can be either a signal input for measurement, or one of the divider outputs for self-checking. IC8 and IC9 can be regarded either as an amplifier with positive feedback or as a flip-flop. They make the signal into a rectangular wave with sharp edges and reject noise which may appear on the input signal. At any instant of time, either IC8 or IC9 will conduct, but not both at once, because the one that is conducting turns the other one off. The positive half-cycle of the input signal will make IC8 conduct; and once it is turned on, the high

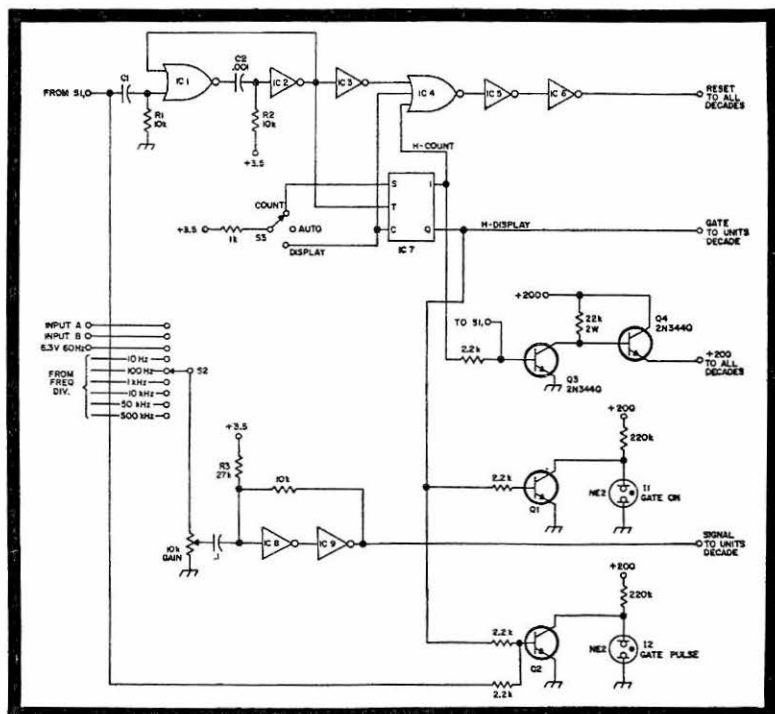


Fig. 5. The control section of the digital frequency counter. IC1 is one-half a Fairchild 914, one-fourth a Motorola MC-724-P or one-third a Motorola MC-792-P. IC4 is one-third a Motorola MC-792-P. IC2, IC3, IC5, and IC9 are one-sixth of Motorola MC-789-P, one-fourth of Motorola MC-724-P, or one-half of Fairchild 914. IC6 is a Fairchild 800 or one-half a Motorola MC-799-P. IC7 is a Fairchild 923 or one-half a Motorola MC-790-P. Q1 and Q2 are 2N3877 or Poly Paks 2N1893.

output from IC9 will supply holding current through R4 to keep it on.

The negative half-cycle will then overcome this holding current and turn off IC8, whereupon the holding current will be removed and IC8 will continue not to conduct.

A small amount of noise riding on the input signal will not be able to overcome the holding current and will, therefore, not make the circuit change state.

The resulting rectangular wave is fed to the units decade at all times, and the necessary gating is done in the first JK flip-flop of the units decade. Provision for gating already exists in the JK and it is simpler to use it than to do the gating in the control section.

The remainder of the control section can exist in either of two states: **count** or **display**. We will discuss these quiescent states before we examine how it gets from one to the other. In the count state, the 1 output of IC7 is high and the 0 output is low. If S1 is not in the X1 position, the high 1 output of IC7 turns on Q3 and turns off Q4, thereby turning off the neon lamps. The low 0 output of IC7 goes to the gate input of the units decade and allows it to count. It also turns off Q1 so that the "gate on" light will be illuminated. The "gate pulse" light will be turned on if a gate pulse is present.

The opposite conditions exist in the display state. Power is applied to the neon lamps through Q4, and a high output is supplied to the gate so that further counting cannot occur, and both Q1 and Q2 are turned on so that the two gate lamps are shorted and not illuminated.

To understand how state changes, assume a display and S3 is in the automatic position. IC1 and IC2 form a monostable multivibrator which supplies the reset pulse and the trigger for IC7. The positive-going edge of the rectangular wave from the frequency dividers turns on IC1 momentarily and this makes the output of IC2 go high. Furthermore, this holds IC1 on until R2 charges up C2 again, whereupon the output of IC2 goes low again. The result is a short pulse which occurs once every timing period. Since the unit is displaying (and automatic), this pulse will be passed by IC3, IC4, IC5, and IC6, inverted each time, and appears as a high pulse to reset the counters. The trailing edge of the pulse from IC2 will toggle IC7, putting us in the count mode. The next pulse from IC2 will not reset the counters because IC4 has a high input from IC7 and, reset can only occur if all three inputs to IC4 are low. The

trailing edge of the pulse still toggles IC7, however, and we are in the display mode; displaying the number of input pulses that occurred between two timing pulses.

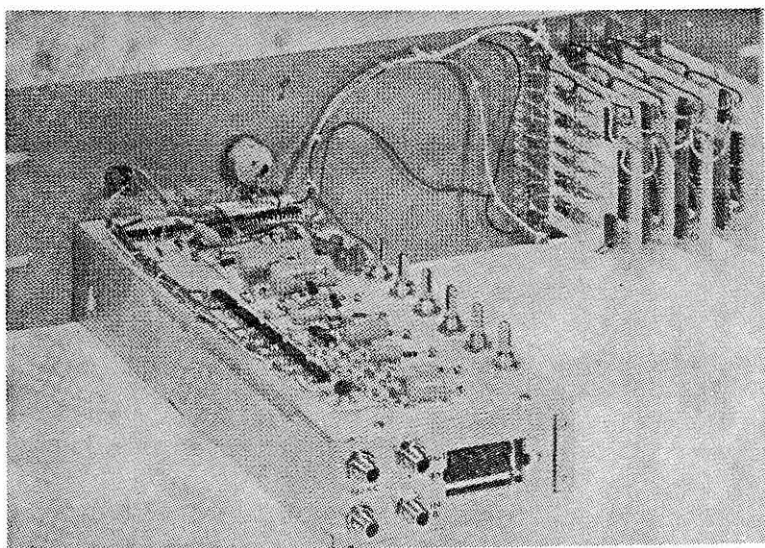
The switch, S3, is used if you want to count, or display, for a multiple of the basic timing period. The switch itself does not switch the counter to display or count, since only the timing pulses can be allowed to do this; rather, it prevents the counter from going into the other state. The "display" position of this switch is useful if you have just made a critical count and want to hold it a few seconds to make sure of writing it down correctly. It is also useful if the circuit for blanking the neon lamps isn't working or isn't yet built and you want to make a reading on the higher ranges. In this case it is difficult to read the display on the automatic position because you will see both the counting and the display, but placing S3 on "display" will hold the last count and allow you to read it.

The switch can be thrown to "display" either during count or during display. In either case, a timing pulse will still switch IC7 from count to display at the right time, but the next timing pulse will not put it back on count due to the high level on the clear input. Also, the counter will not be reset due to the high input of ICV which will hold its output low.

The count position of S3 is normally used only on the X1 position of S1, and is used when you want a gate time of several seconds for an error of less than 1 Hz. If you start a 10-second run and the signal starts to fade, you can stop the test at the next timing pulse by throwing the switch to display and still obtain a meaningful reading. To make a 10-second run, you start with S3 on display, and throw it to count when everything is ready. The next timing pulse will put you in the count mode, but the next one will not put you back on display.

Each timing pulse will flash the "gate pulse" lamp once, and after it has flashed 10 times, you put S3 back on display. The next pulse will put the counter on display and you will be able to read the frequency in tenths of hertz. With a little practice, you will find that running a multiple second count is much easier than reading about it.

In wiring the counter it should be remembered that the supply to the neon bulbs is a 200V square wave because of the lamp blanking circuit, and also, the collectors of Q1 and Q2 (Fig. 5) have 60V pulses on them since they turn on neon lamps. Both of these must be kept away from the inputs to the ICs; otherwise, erratic operation will result. In particular, the



All of the count-control circuitry is mounted on the large chassis to the left. The small perforated boards on the right each contain one decade counter.

200V lead to the counters must not be cabled with the signal and gate inputs to the counters and the leads to I1 and I2 must be kept at least an inch away from the leads of S3. If the counter shows any erratic operation which cannot be easily explained, the blanking circuit should be disabled by grounding the base of Q3 so that the lamps are on continuously, and I1 and I2 should be shorted to ground. A test can then be made to see if the trouble still exists. Except for these precautions, no other difficulties should be encountered with the unit.

Counting decades

Figure 6 shows the circuit on one counting decade, including neon lamp drivers. The gate input on the units decade is connected to the gate output of the control section, but the gate inputs on the other decades must be grounded since each must accept any pulses put out by the preceeding decade. The actual counting is done by four JK flip-flops and, with the help of the table shown, the reader can follow the count as an interesting exercise. The input pulse following the ninth count makes the decade go back to zero and passes a negative transition on to the next decade making it count once.

Count	A B	B A	C D	D C	E F	F E	G H	H G
0	H	L	H	L	H	L	H	L
1	L	H	L	H	L	H	L	H
2	H	L	L	H	L	H	H	L
3	L	H	L	H	L	L	H	H
4	H	L	H	L	H	L	L	H
5	L	H	H	L	H	L	L	H
6	H	L	H	L	H	L	L	H
7	L	H	L	H	L	L	L	H
8	H	L	L	H	L	L	L	H
9	L	H	H	L	L	H	L	H

Table 1. Truth table showing the proper levels on each of the logic lines of the decade counter.

IC5 through IC12 are needed to amplify the voltage output of the JK flip-flops. The JK flip-flops give only 1V output with light external loading due to the fact that they internally load their own outputs. This was not found sufficient to drive the resistor gates used for the neon lamp drivers. An inverter, however, gives almost full supply voltage when lightly loaded and drives the resistor matrix satisfactorily.

It is necessary to use discrete transistors to drive the neon lamps at the present state of the art, but these are not expensive, especially if Poly Paks 2N1893s are used. The tran-

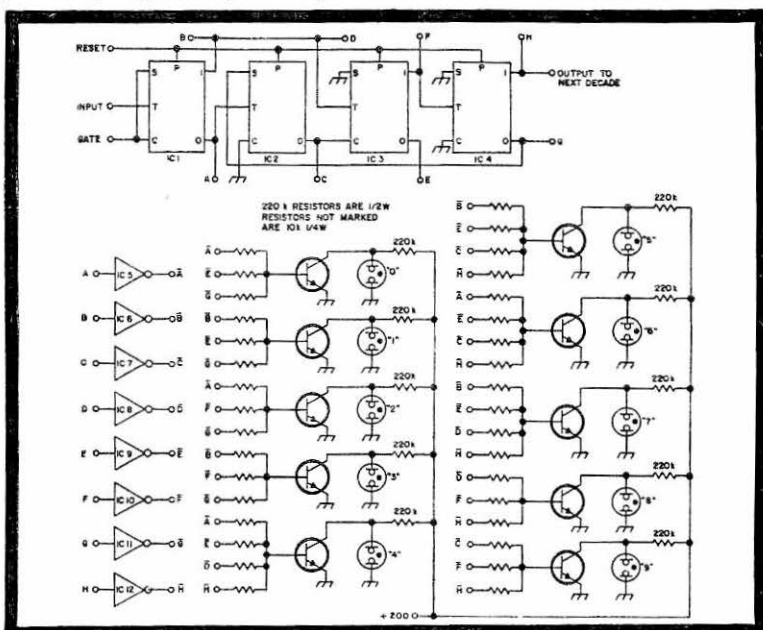


Fig. 6. A typical counting decade. In this circuit integrated circuits IC1 through IC4 are one-half Motorola MC-790-P or Fairchild 923. IC5 through IC9 are one-sixth Motorola MC-789-P, one-fourth Motorola MC-724-P or one-half Fairchild 914. All transistors are 2N3877 or Poly Paks 2N1893. All neon lamps are NE-2.

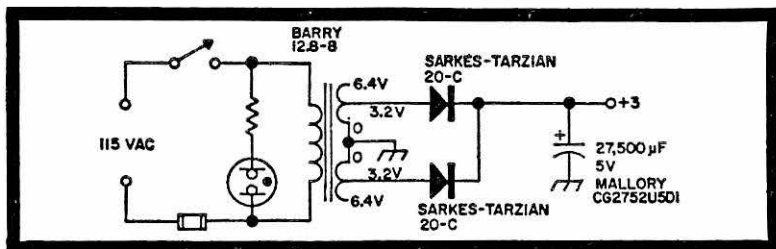


Fig. 7. Three-volt power supply for use with the integrated circuit frequency counter. A truth table showing the proper levels on each logic line are shown in Table 1.

sistors are used as shunts across the lamps. This makes gating simpler and also limits the voltage across each transistor.

For a given count one lamp must be on and the other nine off. The driver for the desired lamp must have low level on all its inputs so that the transistor will not conduct, allowing the lamp to light. The other nine drivers must have high level applied to at least one input; this will be sufficient to extinguish the lamp, regardless of what appears on the other inputs.

The gating of the lamps could have been done entirely with ICs, but this method was found to be simpler and cheaper, at least at the present state of the art.

In testing the decades, +200V must not be applied unless all transistors, which are in place, have neon lamps across them. Otherwise, if a transistor is not conducting, the collector voltage rating will be exceeded since there is no neon lamp limiting the voltage. Also, if +200V is applied to a decade but +3.5V is not, all lamps should light since the logic circuitry only acts to short out the undesired lamps. No harm is done by this and it is a quick way to check the lamps and driver transistors. If a lamp does not light under this condition, its driver transistor should be suspected first.

Power supply

The counter, as shown in Fig. 6, requires about 1A at 3.5V and 40 mA at 200V. Neither supply needs to be regulated and the ICs will work on any voltage from 3.0 to 4.5V, although 3.6V (± 10 percent) is recommended by the manufacturer. The power supply used by the author is shown in Fig. 7.

An 8A transformer was used because it didn't cost much more than a 2A one in the same series. The 2A unit would

probably work and would save space and weight. For the 200V supply, anything from 150V on up would work, although with anything much over 200V, the 220K collector resistors must be increased or a dropping resistor must be provided. If this voltage is taken from a supply powering other equipment, it must be remembered that the current drawn will be a 40 mA (peak) square wave at 5, 50, 500, or 5000 Hz, which may cause a buzz to be heard on the other equipment.

Construction

The individual counting decades are built on See-Zak MM-492 boards and the remainder of the unit on a See-Zak MM-512 board mounted on See-Zak R-25 and R-212 rails. See-Zak M-25 terminals are used for the larger components, including the Fairchild ICs. The hole spacing on these boards is 0.2 in., whereas the Motorola ICs require 0.1 in. spacing; therefore, seven extra 1/16 in. holes must be drilled for each Motorola IC between existing holes. Connections to the Motorola ICs are made with 26 gage bare wire covered with Teflon spaghetti. No other construction details are given, since the writer is more interested in circuitry than packaging; other builders will probably have ideas of their own. The use of printed circuits would be ideal.

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